August 2012

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Will Curiosity find LIFE on MARS?

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HOW twin rovers found water on Mars p. 26

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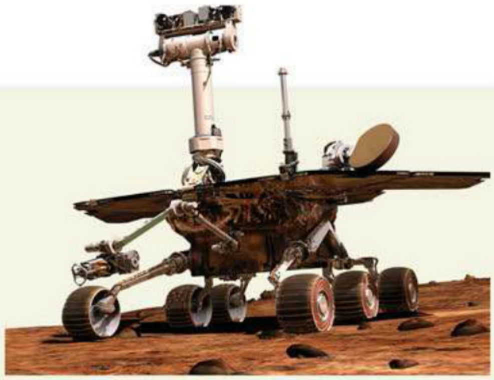
ON THE COVER

The Mars Science Laboratory, called Curiosity, should land on the Red Planet on August 6. It will explore Gale Crater for signs of past and present life.

August 2012



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COLUMNS

IN EVERY ISSUE

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This Month in *Astronomy*

Truth and science

by David J. Eicher

Recently, I saw a clip of an Arizona state senator arguing for uranium mining in her state in part because "Earth is 6 thousand years old." Using radioactive elements like the very uranium she was talking about, we know that Earth is 4.5 billion years old. It's staggering that we have such ignorance in the year 2012.

It does raise the point about the relationship between science and truth. Just what means do people use to determine what is true and what is false? Let's examine them from the worst to the best.

Intuition is highly subjective and preferred by theologians. It relies on guesswork, dreams, imagination, inspiration, revelations, and visions, and may have no basis whatsoever in reality. Ancient philosophers considered intuition "self-evident" unless they were faced with opposing viewpoints. In this case, they simply declared the opposition false, heretical, demented, or blasphemous. If I started believing that everything in my dreams were true, well, let's just say it would be a more interesting world than it really is.

Authoritarian methods are derived from expert testimony from parents, siblings, relatives, friends, neighbors, teachers, clergy, politicians, and celebrities. This kind of truth is reinforced by sheer repetition. It's the knowledge we grow up with and becomes so-called common sense. Why should we believe it? Ya know, because this guy said it!

Rational methods use formal deductions based on logical constructs and mathematical procedures. These involve things like probability, casual interpolations, analogies, semantics, statistics, and syllogisms. Although mathematical methods of determining the truth are far more reliable than dreams or what some guy happens to tell you, they still have their limitations.

Empirical methods have always been favored by scientists. These methods use careful observations and experiments to document the truth in a repeatable way by uncoerced investigators. When the force of gravity on Earth has been measured a hundred million times by hundreds of thousands of people over the past several centuries and they all get the same answer, it gives you good confidence it's the truth.

The usual criticism of empirical methods is that coincidental observation does not lead immediately to firm, dependable conclusions. *But that's exactly what makes it strong and reliable!* The truth as we best know it is always continuously being altered or improved upon on smaller and smaller scales by later discoveries and observations. Scientific knowledge is in a state of continual refinement.

So be patient with science, and trust it to provide the best truth of the cosmos around you. Save your dreams for fun and fantasy. If that guy tells you something is so because he says it's so, have the independent ideas to challenge him. Get the truth at the source, where humans have found it in the best and most reliable way for half a millennium — observational science.

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 40, Number 8

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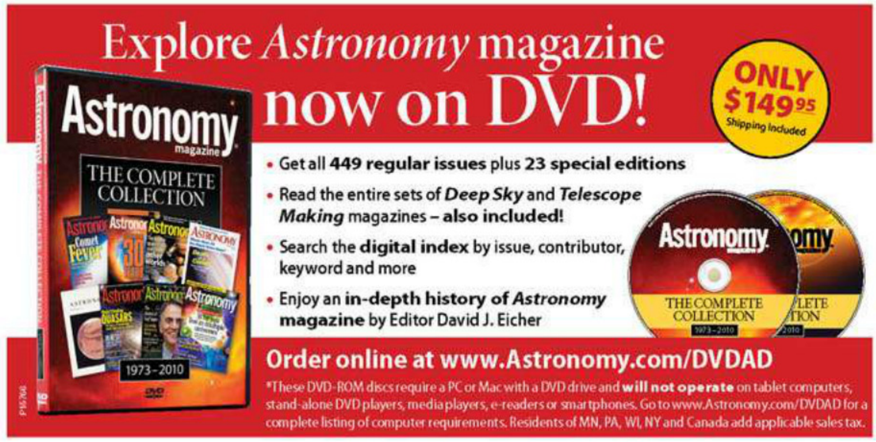
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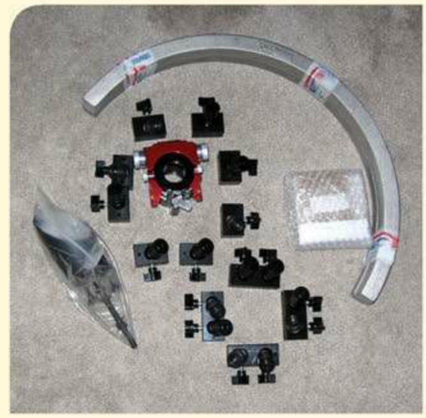
Great tip

I can't begin to tell you how much Senior Editor Michael E. Bakich's "Wander winter's deep sky" (December 2011) influenced me. Before reading the article, I was already working on a design for the next telescope I will build. It will be a replacement for my 17.5-inch Dobsonian, which has become too heavy for my ailing back and joints to manage. So, after waffling back and forth between 12.5 and 14.5 inches, I settled on the safer choice of 12.5 inches.

Ah, but enter Bakich. After reading his article, I saw that I couldn't get past Thor's Helmet (NGC 2359) with that aperture. It didn't take long for me to switch to a 14.5-inch mirror and stay switched. I plan to have my newest scope see first light at the Wisconsin Observers Weekend in July. Thank you for helping me come to my senses.
— **Steve J. B. Bouton,** Evanston, Illinois



New parts for a 14.5-inch scope became necessary for reader Steve J. B. Bouton after reading Senior Editor Michael E. Bakich's "Wander winter's deep sky" (December 2011); his plan for a 12.5-inch telescope would no longer do. Steve J. B. Bouton

Exactly what I thought

I am so busy that I rarely comment on anything I read, but I stopped everything I was doing to write to *Astronomy* after reading an article in your magazine. I don't think anyone, including me, could have written their opinions as clearly, completely, or eloquently as Brian May did in "What are we doing in space?" (February 2012). This gives me hope that there are a lot of us who agree with his statements. I thank you, Brian May, for being so honest and to the point, and speaking my mind as well as yours. And thank you, *Astronomy*, for being brave enough to print it! This article alone is worth far more than a lifetime of subscription costs, even if you never printed another word. — **S. A. Leonard,** Ocala, Florida

Bettering science education

With all the recent discussion of science education, I wanted to mention a program we have in India that is successful at identifying talented young scientists with an interest in astronomy. The National Astronomy Olympiad Programme encourages students with good foundations in physics and mathematics and an interest in astronomy to pursue further studies.

Some 15,000 students are initially invited to apply to represent India in the International Olympiad in Astronomy and Astrophysics (IOAA). After undergoing two exams based on physics, mathematics, and a bit of general astronomy, we narrow the list down to about 35 senior students and 20 junior students. We then invite them to participate in a 20-day astronomy workshop, and from that group we select five students to represent India at the IOAA and three for the International Astronomy Olympiad.

Of the 55 students we've sent to the competitions over the past 10 or so years, 42 are pursing astronomy, physics, chemistry, biology, or mathematics for their careers. We believe that the program has done well in identifying and encouraging talented students to pursue a career in science.
— **Suhas B. Naik-Satam,** Nehru Planetarium, Mumbai, India

Correction

In the time line at the bottom of page 33 of the article "What has astronomy done for you lately?" (May 2012), FFT should be an abbreviation for "Fast Fourier Transform," not "Fast Fourier Transfer." We apologize for the confusion. — ***Astronomy* Editors**

Web Talk

What's new at Astronomy.com. **by Karri Ferron**

A community on the go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More features on Astronomy.com go mobile

It's easier than ever to stay connected with your astronomy community. *Astronomy*'s mobile site now lets you chat in the forums, check out the latest images in the Reader Photo Gallery, comment on staff blog posts, and more — all from your smartphone or tablet. Just click on the "Community" tab, log in with the same registration information you use on Astronomy.com, and you'll have access to all of your private conversations, active forum threads, and astrophotos. With this update, sharing highlights of your observing session can happen in real time, and you no longer have to wait until you have access to a computer to ask that burning cosmological question. Bring the Astronomy.com community with you everywhere you go using **www.Astronomy.com/mobile**.

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OBSERVING TOOLS

Weekly podcast

Each week, *Astronomy* Senior Editor Michael E. Bakich records a podcast featuring three or more objects you can see in the night sky in the next seven days: At least one of them you can find through a small telescope, and two or more are deep-sky targets to seek out with an 8-inch or larger instrument. For each, Bakich provides detailed observing information, interesting historical anecdotes, and other fun facts. Registered users, check back each Thursday to see what objects he'll highlight next at **www.Astronomy.com/podcast**.

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Strange**Universe**

by Bob Berman

Space: women needn't apply?

Debra Elmegreen challenges astronomy's anti-female legacy.

Let's do something different and tackle a *sociologically* odd topic. It's the shameful fog that blanketed our beloved astronomy for centuries — the exclusion of women.

Take Maria Mitchell (1818–1889), America's first female professional astronomer. If you're ever on the enchanted island of Nantucket off the coast of Massachusetts, you can visit her old house and observatory, where she became instantly famous in 1847 by discovering a comet. It's hard not to love this long-gone woman who wrote, "Standing under the canopy of stars ... you could scarcely do a petty deed."

Her story had a rare happy ending as she became the very first professor at a brand new college named Vassar. But few others fared as well. Annie Maunder's (1868–1947) acute mind played a big behind-the-scenes role in the success of 19th-century solar pioneer Edward Maunder when the British couple clarified the 11-year sunspot cycle. Yet, despite being voted mathematician of the year at Cambridge University and passing her final qualifying exam, she was denied a degree simply because she was a woman.

Such discrimination continued. At the famous 200-inch Hale Telescope on Palomar Mountain in California, women were simply not welcome. And when Jocelyn Bell Burnell discovered pulsars in 1967, the revelation won a Nobel Prize — for her research advisor, who did little of the work. Burnell wasn't even mentioned.

Into this disgraceful legacy came Debra Meloy Elmegreen. Now completing her two-year presidency of the American Astronomical Society (AAS), this woman represents our nation's professionals.

I've interviewed many of our top brilliant women, like the Carnegie Observatories' Wendy Freedman and planetary guru Heidi Hammel, and wish I had crossed paths with Vera Rubin, now in her 80s, famous for her groundbreaking dark-matter work even though she couldn't get into Princeton's graduate program because it was men only. But I'll let Elmegreen serve as sort of our breakthrough woman astronomer.

Browse the "Strange Universe" archive at www.Astronomy.com/Berman.

Debra Meloy Elmegreen is an astronomy professor at Vassar College in Arlington, New York, and president of the American Astronomical Society. Debra Meloy Elmegreen

It's really an excuse. Fact is, I adore her. Everyone does. That's possibly why she was selected as the first-ever AAS president from a small college. Being likeable counts.

She also has guts. Maybe 15 years ago, I invited her to be my guest on a radio call-in show, and she agreed even though it meant flying 45 minutes to another city in my beat-up four-seat hippie plane. So, this first-ever "Strange Universe" bio has a dual purpose: first, to do my part to help erase that terrible anti-woman astro-legacy; and second, to salute the person who has been the official spokesmammal for American astronomers since 2010.

Elmegreen grew up in Fairfax, Virginia. As a teenager, she ground her own telescope mirror and built a 16-square-foot (1.5 square meters) shortwave receiver to study Jupiter. She then wrote an article for this magazine ("Tuning In On Radio Astronomy: Building Your Own Radio Telescopes," December 1977) and won all sorts of Westinghouse and other science fairs. The consummate geek, she'd hold star parties in her backyard. The magazine *Seventeen* decided to do an "Up and Coming Teen" feature on her, but when they asked Elmegreen for her astrological sign and whether Jupiter was in her horoscope, she disclaimed that nonsense, so the publication killed the article.

No matter. She got her bachelor's degree in astronomy from Princeton University — the first woman to do so — and then her master's and doctorate from Harvard. "In those rare moments of total quiet with a dark sky, I again feel the awe that struck me as a child," she says. "I enjoy observing galaxies at optical, infrared, and radio wavelengths, and hope to contribute more to the understanding of galaxy star formation and structure in galaxies."

She already has. As Vassar's Maria Mitchell Professor of Astronomy, she often uses the Hubble Space Telescope and is especially focused on colliding galaxies and how their structure in the early universe is so different from those today. It was she who coined the term *flocculent galaxy* for bizarre ones like NGC 7793 that have many short chaotic arms instead of the two elegant spirals displayed by "grand design" galaxies.

Despite her research workload, she teaches five courses a year at Vassar, while her duties as AAS president take her to places like Congress and the Vatican.

When the movie *Thor* came out starring Natalie Portman as an astrophysicist, a magazine cited Elmegreen as the real-life model. Indeed, the portrayal of fictional female astronomers like comet-observing Darryl Hannah in the film *Roxanne* and alien-searching Jodie Foster in *Contact* shows how far we've recently come. Although just 22 percent of professional astronomers are women, for the under-30 pool the number has now grown to 40 percent.

For the moment, though, I guess we can live with "the man in the Moon."

Contact me about my strange universe by visiting **http://skymanbob.com**.

by Stephen James O'Meara

The mystery of daylight aurorae

Can these nighttime light shows compete with the Sun's glare?

Aurorae, the northern and southern lights, are one of the night sky's most animated spectacles. Some even splash their colors across twilit skies. But has anyone ever seen an aurora in the daytime?

On October 25, 1870, observers across the British Isles witnessed a brilliant crimson display, which apparently began at about 5:30 P.M. (some 50 minutes after sunset). A couple of months later, in a letter published in the December 8, 1870, issue of *Nature*, James Cubitt reported that he first spotted activity from Huntingdonshire at 4:30 P.M. (about 10 minutes *before* sunset).

Cubitt described the daylight activity as a "remarkable pale luminous appearance" some 25° above the eastern horizon, where he saw "two arcs of faint white lines, one above the other, both radiating outwards with a number of short points." He added that the sighting interested him because "it seems that the greatest disturbance of the telegraphs happened before the *evening* display of the aurora."

U.S. Air Force Senior Airman Joshua Strang

The aurora borealis, or northern lights, is one of the most dazzling sights of the night sky. But could the most intense displays glow strongly enough to be visible in the daylight?

The letter brought swift criticism. In the next issue of *Nature* (the following week), George F. Burder said he ventured "to believe *not*" Cubitt's and others' similar claims. After reviewing historical cases, Burder concluded that all such daylight sightings suffer from "errors of observation." In Cubitt's case, he suspected that the "object observed was nothing more than a remarkably symmetrical form of cirrus cloud."

The debate continued into the following year with W. G. Thompson recalling, in the March 2, 1871, issue of *Nature*, a brilliant auroral display in 1870 that, "beyond a doubt," could be seen in the daylight. "In the autumn of last year," he wrote, "my eye was attracted by an unusual motion, in what at the first glance appeared to be a light fleecy cloud, but was in reality a broad ribbon of Aurora of a yellowish white colour, which changed its form and position with the peculiar streaming motion of the Aurora, sometimes almost fading entirely and again recovering its comparative distinctness."

Stephen James O'Meara

Faint auroral activity during twilight, such as this wispy example the author captured over Iceland, shows just how difficult the ethereal lights would be to see against a daylit sky.

John Jeremiah also disagreed with Burder, and in a May 1871 issue of *Nature* set out "to prove the fallacy of such reasoning," by sharing with readers nine historical accounts of daytime aurorae he found dating from A.D. 1122 to 1871.

Personal finds

Several years ago, while conducting unrelated research at the Boston Public Library, I found two additional claims of daylight aurorae sightings. The first dates to 1786 and occurred during a Danish expedition to the Arctic. As Sir John Barrow described in his 1818 work, *A Chronological History of Voyages into the Arctic Regions*: "A phenomenon was observed during the day-time which [the captains of the two ships involved] concluded to be the aurora borealis." The activity consisted of "streaks of light columns and luminous points" shooting up from the horizon, "darting and changing their shapes in the same manner as [an aurora]." They saw the same phenomenon the following day, but more faintly. "If it was the aurora borealis," Barrow wrote, "it is probably the first time it has been observed by daylight, and when the sun was above the horizon."

The second claim appeared in Sir John Franklin's 1824 *Narrative of a Journey to the Shores of the Polar Sea, in the Years 1819, 20, 21, and 22*. In an appendix, he included this extract from Dr. John Richardson's journal: "March 8, 1821. At 6 P.M, before the daylight was gone, the Aurora appeared ... stretching up towards the zenith. At seven, two faint arches crossed the zenith. The Aurora was bright and copious all the evening."

If you have a daytime aurora experience of your own you'd like to share, please let me know at someara@interpac.net.

Browse the "Secret Sky" archive at www.Astronomy.com/OMeara.

App-reciate it! As of April 3, fans of NASA's Kepler mission could download *Kepler Explorer*, a free app showcasing the discoveries of the planet-hunting quest.

For the latest news on space discoveries, spacecraft missions, and sky events, visit **Astronomy.com/news**

Astronews

Particle shower. The search for the source of ultra-high-energy cosmic rays has led to scientists crossing off one leading theory: Gamma-ray bursts do not rev up these particles to their extreme energies. NSF/J. Yang

Gamma-ray bursts not responsible for extreme cosmic rays

Ever since scientists discovered ultra-high-energy cosmic rays (particles from space) in the mid-19th century, they've been searching for what revs up these particles to such extreme energies. Theories proposed that either the explosive death of an extremely massive star (resulting in a gamma-ray burst [GRB]) or jets shot out from supermassive black holes could accelerate cosmic rays to energies 1 million to 1 billion times those created in the largest Earth-based accelerators. Now, a study published in the April 19 issue of *Nature* suggests that GRBs are not responsible for ultra-high-energy cosmic rays, thus ruling out one of the leading possibilities.

The team analyzed data from IceCube, a cubic-kilometer detector embedded in the Antarctic ice. The IceCube collaboration looked for neutrinos — particles that interact weakly with matter and have little mass — that are produced as ultra-high-energy cosmic rays decay into other particles. The researchers compared the positions of more than 200 GRBs to IceCube neutrino data.

"According to a leading model, we should have expected to see 8.4 events corresponding to GRB production of neutrinos in the IceCube data," says Spencer Klein of the Lawrence Berkeley National Laboratory in California and a member of the IceCube collaboration. "We didn't see any, which indicates that GRBs are not the source of ultra-high-energy cosmic rays."

Ruling out one method does not confirm that the other leading theory (jets from active supermassive black holes) is the answer to this decades-old puzzle. Scientists will use IceCube and other particle detectors to continue searching for the cause of ultra-high-energy cosmic rays. — **LIZ KRUESI**

Slower, older collision reveals dark matter

Material separation. In the Musket Ball Cluster, normal matter and dark matter have been wrenched apart. Hot gas is shown in red while blue indicates the presence of this elusive substance. X-ray: NASA/CXC/UC Davis/W. Dawson, et al.; Optical: NASA/STScI/UC Davis/W. Dawson, et al.

In 2006, scientists discovered the Bullet Cluster, the first galaxy cluster merger found where normal matter was wrenched from dark matter — material that doesn't emit any light or radiation but can be detected through gravitational lensing. Since then, astronomers using NASA's Chandra X-ray Observatory have uncovered six similar examples, the most recent one released April 12. The newly discovered Musket Ball Cluster, named so because it is older and slower than the Bullet, is about two to five times further along in the merger process than previously observed systems. — **KARRI FERRON**

Dawn relays results from Vesta

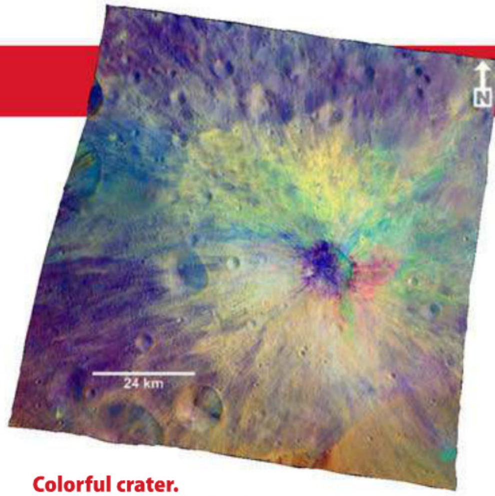
After more than nine months orbiting the giant asteroid Vesta, NASA's Dawn spacecraft is painting a better picture of the second-most massive object in the main asteroid belt. In a presentation at the European Geosciences Union meeting in Vienna, Austria, on April 25, scientists revealed new data about Vesta's surface composition, internal structure, and temperature fluctuations.

Images from the spacecraft's visible and infrared mapping spectrometer show a variety of surface minerals and rock patterns. Many features are composed of iron- and magnesium-rich minerals, similar to the composition of earthly volcanic rocks. Dawn also revealed an area of banding near a south pole crater; it shows contamination from space rocks bombarding Vesta in layers closer to the surface and more original characteristics of the asteroid in layers below.

"These results from Dawn suggest Vesta's 'skin' is constantly renewing," says Maria Cristina De Sanctis, lead of the visible and infrared mapping spectrometer team based at Italy's National Institute for Astrophysics in Rome.

In addition to imaging, Dawn has made extensive ultrasensitive measurements of Vesta's gravitational influence on the spacecraft, which give researchers clues about the asteroid's unusual densities within its outer layers. Scientists also have created the highest-resolution surface temperature maps of any asteroid. Dawn's data reveal that Vesta can vary in temperature from –10° Fahrenheit (–23° Celsius) to at least –150° F (–100° C), or the lowest reading the spacecraft can record.

Because of Dawn's success so far, NASA announced April 18 that the spacecraft will spend an extra 40 days at Vesta, until August 26, before departing for its scheduled arrival at the dwarf planet Ceres in February 2015. — **K. F.**



Colorful crater. The comparatively fresh impact crater Vibida on Vesta shows a colorful blanket of ejecta material in this composite false-color image. The different kinds of materials reflect a complex interplay between ancient volcanic and impact processes that shaped the asteroid's crust. NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

A young cluster's heated environment

The stellar cycle. Winds and radiation from a cluster of young stars near the upper left of this image push stellar material into a compact region, thus encouraging the next generation of stars to form. This cluster, NGC 6604, lies about 5,500 light-years away in the constellation Serpens the Serpent. Astronomers also see a perplexing column of hot gas extending 650 light-years above the hot young stars, but they don't understand the structure's formation. The European Southern Observatory released this image April 25. — L. K. ESO

QUICK TAKES

GARRADD TO KNOW YOU
NASA announced April 13 that its Swift satellite visually captured Comet C/2009 P1 (Garradd) on its path away from the Sun and would continue to track its journey.

EXTENDED DURATION
NASA announced April 5 that it had extended the orbiting Kepler and Spitzer missions for two years, and its involvement in the Planck mission one year.

SENATOR SUPERNOVA
Officials named a recent supernova and a massive database of astronomical data in honor of U.S. Senator Barbara Mikulski, NASA announced April 5.

NO DEAL, NSF
The Giant Magellan Telescope Organization's board of directors announced April 2 that they would not seek funds from the National Science Foundation (NSF).

SENIOR STARS
Researchers have discovered the two oldest known white dwarf stars just 100 light-years away, as detailed in an upcoming paper in the *Monthly Notices of the Royal Astronomical Society*.

NEARLY THERE
Lockheed Martin announced April 16 that it had completed building the Near Infrared Camera for the upcoming James Webb Space Telescope, due to launch in 2018.

TAKE YOUR SEAT
Planetary scientist and author David H. Grinspoon will be the first Baruch S. Blumberg NASA-Library of Congress Chair in Astrobiology, the space agency announced April 16.

SHUTTLING A SHUTTLE
NASA announced April 19 that it had successfully transferred the space shuttle *Discovery* to the Smithsonian National Air and Space Museum.

LIFE'S DEPTHS
Studies of microbial life beneath asteroid craters on Earth indicate that life may exist beneath Mars' craters as well, according to an April 2 paper in *Astrobiology*.

IN MEMORIAM
Chinese astrophysicist and human rights advocate Fan Lizhi of the University of Arizona in Tucson passed away April 6 at the age of 76. — **BILL ANDREWS**

NASA/ESA/R. M. Crockett (Univ. of Oxford)/S. Kaviraj (Imperial College London/Univ. of Oxford)/J. Silk (Univ. of Oxford)/M. Mutchler (STScI)/R. O'Connell (Univ. of Virginia)/The WFC3 Scientific Oversight Committee

Old and brimming. **The elliptical NGC 4150 is one of 260 galaxies astronomers studied to learn about the distribution of low-mass compared to high-mass stars, which can tell them about galaxy evolution.**

Early galaxies formed stars differently

To understand galactic evolution, astronomers need to know about galaxies' contents and their distribution of stars of varying masses. For decades, scientists have argued whether the ratio of low-mass stars to massive stars is consistent among different types of galaxies. A new analysis of 260 galaxies that formed early in the universe, and thus are called "early" ellipticals and lenticulars (these have disk components, but are older than spiral types), points to variations in the stellar distribution: Massive old elliptical galaxies have a larger fraction of low-mass stars. The findings appeared in the April 26 issue of *Nature*.

Led by Michele Cappellari of the University of Oxford in England, the astronomers measured the motions of stars compared to their positions to determine the mass distribution of the galaxies. They then measured the emitted light of those galaxies and compared the calculated mass to luminosity. The team also eliminated the possibility that the additional mass is from a mysterious invisible material called dark matter.

The overall trend showed that these early galaxies contain more mass — and thus, more low-mass stars — than a universal stellar distribution would assume. The finding implies that star evolution and formation, and therefore galaxy evolution, differed in the early universe. — **L. K.**

A longer Late Heavy Bombardment?

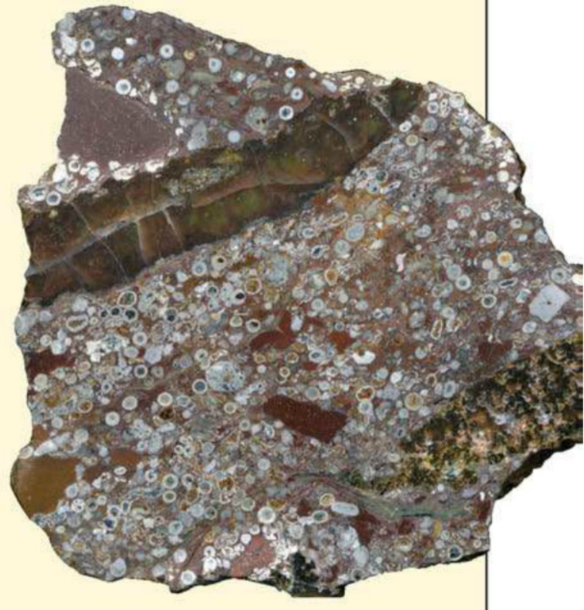
A few hundred million years after our solar system's planets formed, a barrage of asteroids pummeled Earth and the Moon. Scientists believe this period, known as the Late Heavy Bombardment (LHB), lasted from roughly 4.1 to 3.8 billion years ago. However, in two *Nature* papers published online April 25, researchers discuss a method to investigate the record of Earth's impact history and outline the evidence for a longer bombardment period.

Because Earth's tectonic processes and surface weather phenomena destroy the evidence of asteroid impacts (craters), scientists use the Moon's impact history as a guide for our planet's past. This is how they learned about the LHB period.

From crater studies, researchers know that incoming asteroids have huge amounts of energy due to their mass and high speeds. Thus, instead of digging out a trench in the material it hits, the asteroid explodes, vaporizing itself and the target rock. Once the vapor plume cools, it condenses into millimeter-sized droplets called spherules. These droplets fall to the ground, and the millimeter- to centimeter-sized layer is preserved in rock. Scientists know of 14 of these rock layers scattered across Earth. Four date to between 3.47 and 3.24 billion years ago; seven to between 2.63 and 2.46 billion years ago; one to 1.85 billion years ago; and two from tens of millions of years ago, including the K/T impact that led to the extinction of the dinosaurs. All of these layers indicate that huge collisions occurred in those time frames.

From the thickness of the spherule layers, Jay Melosh and Brandon Johnson of Purdue University in West Lafayette, Indiana, estimated the sizes and speeds of the asteroids that led to the molten-rock droplets. They calculated that most of the space rocks were substantially larger than the one responsible for the K/T transition. These results suggest that the LHB did not abruptly end 3.8 billion years ago, as suspected, but instead gradually declined through about 2 billion years ago.

The other study offers an explanation for a much longer LHB period. William Bottke of the Southwest Research Institute in Boulder, Colorado, and colleagues say the impactors came from an extended portion of the inner asteroid belt, which they call the "e-belt."



Telling rock. **A sample from a layer of mineral inclusions in rock found in Western Australia dates to about 2.63 billion years ago. By analyzing this and 13 other spherule layers across Earth, scientists estimated the size and speed of impacting asteroids and suggest that the Late Heavy Bombardment period lasted until around 2 billion years ago.** Bruce M. Simonson

Planetary scientists' leading theory of the early solar system fits observations — such as the planets' current orbits and the LHB period. This "Nice model" says that the giant planets began closer to the Sun, but about 4 billion years ago Jupiter and Saturn passed through an orbital resonance that caused chaos in the solar system. This gravitational shift pushed the orbits of Uranus and Neptune farther out and into a region of space rocks. These comets and asteroids went flying into the inner solar system and slammed into Earth and the Moon (along with the other inner worlds).

Bottke's team performed simulations of the Nice model with an inner e-belt between 1.7 and 2.1 astronomical units (where 1 astronomical unit is the current average Earth-Sun distance). In this model, asteroids pummeled Earth and the Moon for a longer period, extending the LHB to some 2 billion years ago and supporting the time frame that Melosh and Johnson found with their spherule-layer analysis. — **L. K.**

Disappearing dark matter. This artist's concept depicts the expected distribution of dark matter (in blue) around the Milky Way Galaxy. New findings, however, suggest that the mysterious substance may not be as prevalent after all. ESO/L. Calçada

Lack of dark matter surprises scientists

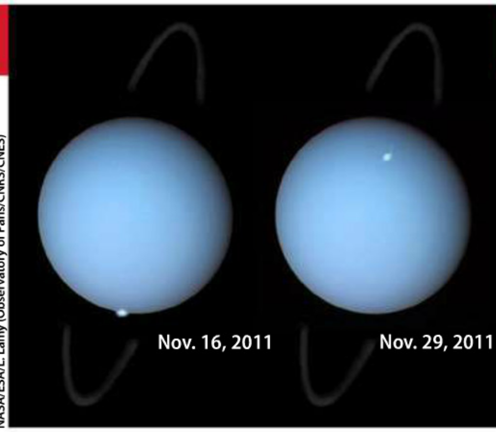
Dark matter sure isn't making things easy for scientists. They had expected the area around our Sun to be full of the stuff, but an upcoming paper in *The Astrophysical Journal* reveals that our galactic neighborhood is dark matter free. Not only does this contradict the current understanding of how galaxies form and behave, but it also likely dooms earthbound searches for the elusive substance.

"Our calculations show that it should have shown up very clearly in our measurements," says lead author Christian Moni Bidin of the University of Concepción in Chile. "But it was just not there!" The hypothetical substance accounts for about 80 percent of the universe's matter and interacts only through the force of gravity, rendering it almost perfectly invisible. By studying the movements of stars and other objects, astronomers can infer the presence of dark matter, despite being unable to explain it.

But the new findings, derived from the most accurate analysis yet of stellar motion within 13,000 light-years of the Sun, contradict expectations. Rather than bursting with dark matter, the area is almost entirely devoid of it. Only an unlikely distribution of the substance in the Milky Way can explain this outcome while keeping current models intact. Further, the lack of dark matter in our vicinity makes any attempts on Earth to detect it unlikely to succeed.

Unfortunately, the new results don't erase the original need for the theoretical matter to explain galactic behavior, either. "If dark matter is not present where we expected it, a new solution ... must be found," says Moni Bidin. "The mystery of dark matter has just become even more mysterious." — **B. A.**

NASA/ESA/L. Lamy (Observatory of Paris/CNRS/CNES)



Uranus aurorae

White lights. For the first time, scientists using the Hubble Space Telescope glimpsed Uranus' aurorae, a result of charged particles from the Sun colliding with molecules in the planet's atmosphere. The aurorae appeared far from the poles because Uranus' magnetic field is inclined 59° to its spin axis. The images appeared in the April 14 *Geophysical Research Letters*. — K. F.

Ironic impacts Asteroids acquired their "iron-loving" elements — a heavy class that bind tightly to iron — through impacts, just like Earth, according to an April 6 paper in *Science*.

NASA/ESA/D. Lennon, E. Sabbi (ESA/STScI)/J. Anderson, S. E. de Mink, R. van der Marel, T. Sohn, and N. Walborn (STScI)/N. Bastian (Excellence Cluster, Munich)/L. Bedin (INAF, Padua)/E. Bressert (ESO)/P. Crowther (Univ. of Sheffield)/A. de Koter (Univ. of Amsterdam)/C. Evans (UKATC/STFC, Edinburgh)/A. Herrero (IAC, Tenerife)/N. Langer (AifA, Bonn)/I. Platais (JHU)/H. Sana (Univ. of Amsterdam)

Up close star formation

Hooray, Hubble! When the Hubble Space Telescope has a birthday, we all get a present. In honor of the orbiting observatory's 22nd year in space, the Hubble team released this scene of unruly star birth April 17. Some 170,000 light-years away in the Large Magellanic Cloud, one of the Milky Way Galaxy's irregular neighbors, lies the Tarantula Nebula, and within it this region known as 30 Doradus. This area hosts the most massive stars ever seen, and, appropriately, this image represents one of the largest composites ever created from Hubble photos. — B. A.

New insights into stellar death

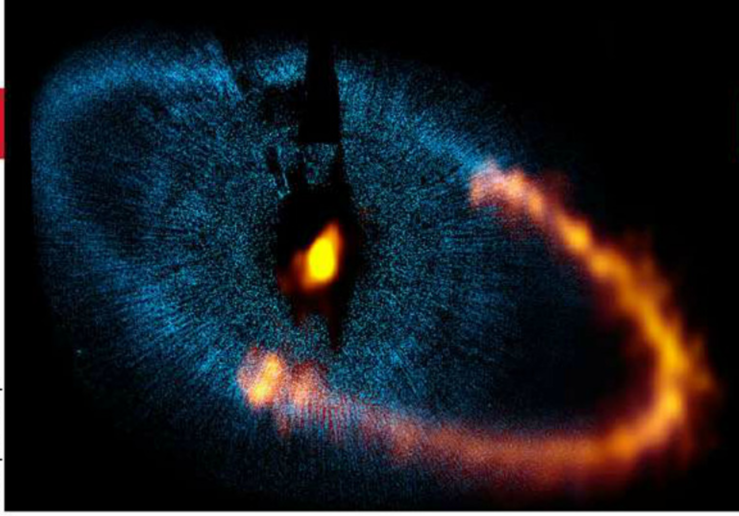
Whether in humans or stars, death is a big — and largely unknown — part of the life cycle. A *Nature* study published April 12 may start to change that, however, as it describes events surrounding the demise of Sun-like stars in unprecedented detail. "We are now a big step further in understanding this cycle of life and death," says co-author Albert Zijlstra of the University of Manchester in England.

When intermediate-mass stars like the Sun reach the red giant phase at the end of their lives, they begin to emit a "super wind" millions of times stronger than ordinary stellar wind. Over some 10,000 years, this process removes about half of the star's mass, but astronomers weren't sure exactly how it worked. They had suspected that the uppermost stellar layers formed tiny dust grains, which the star's radiation then pushed outward. The problem was that such grains would theoretically burn up before traveling far.

The researchers solved this mystery by studying three red giants at exceptionally high resolution. They found surprisingly large dust grains (about 600 nanometers across) less than a stellar diameter away from each giant, suggesting that the dust didn't absorb the star's light directly, instead likely reflecting it.

Not only does this explain the super wind's behavior, and thus shed light on how stars like our Sun will one day die, but it also helps scientists understand how planets like Earth form. "The dust and sand in the super wind will survive the star and later become part of the clouds in space," says Zijlstra. "Our own Earth has formed from star dust." — **B. A.**

Death throws. Middleweight stars like our Sun eventually will become red giants, as depicted in this illustration. Scientists have recently figured out a way to explain how these behemoths can spew out much of their mass without it burning up in the process. David Aguilar/CfA



ALMA (ESO/NAOJ/NRAO); optical: NASA/ESA/ Hubble Space Telescope

Focus: Fomalhaut. Nearby Fomalhaut, the young star near the center of this image, likely has two planets orbiting on either side of a cool dusty ring made up of debris from the collisions of comets. Here, the latest radio emissions (in orange) appear overlaid on visible-light observations (in blue).

FAST STAT

120 SUNS

The light output of the surprisingly dim star cluster Muñoz 1, according to an upcoming paper in *The Astrophysical Journal Letters.*

Exploring Fomalhaut's planetary system

Fomalhaut may not yet be a household name, but perhaps that's just a matter of time. Two recent scientific papers describe the young star's dynamic system, including a dust ring built from thousands of daily cometary crashes and two small planets embedded within the ring.

The first paper, published online April 11 by *Astronomy & Astrophysics*, describes the composition of the dusty ring around Fomalhaut, a star twice as massive as our Sun about 25 light-years away. The extremely cold temperatures within the ring, combined with earlier observations, suggests that fluffy assemblages of dust released from cometary collisions make up its bulk. Because the star would soon blow away the debris from these crashes, the authors speculate that tremendous numbers of daily collisions — enough to pulverize 2,000 comets about 0.6 mile (1 kilometer) across — keep the supply of dust high. "I was really surprised," says lead author Bram Acke of the University of Leuven in Belgium. "To me, this was an extremely large number."

Second, a May 1 paper in *The Astrophysical Journal Letters* focuses on two planets that straddle the dust ring as they orbit Fomalhaut. In fact, it was the sharp edges of the dust ring that allowed the researchers to confirm the planets' presence and even determine some of their characteristics. "The masses of these planets must be small," says lead author Aaron Boley of the University of Florida in Gainesville. "Otherwise, the planets would destroy the ring." Previously, astronomers had suspected that a single larger planet orbited Fomalhaut.

This latter discovery is also significant because it's the first published science finding from the Atacama Large Millimeter/submillimeter Array in Chile, a facility still undergoing construction. — **B. A.**

Venusian voices

British scientists re-created natural sounds from Venus, Mars, and other worlds in a planetarium show that debuted April 4.

BRIEFCASE

Still a ways to go

Voyager 1's Cosmic Ray Subsystem experiment detected an increase in electrons and protons in 2011, implying that the spacecraft is not as close to the border between the Sun's protective bubble and interstellar space as previously thought. William Webber of New Mexico State University in Las Cruces and colleagues analyze the roughly 25 percent signal increase in the March 29 *Geophysical Research Letters*. — L. K.

Venusian oddity

The Sun's coronal mass ejections and the aurorae in Earth's atmosphere are examples of magnetic reconnection. As oppositely directed magnetic field lines break and then combine, this "reconnection" leads to the conversion of magnetic energy into kinetic energy. Scientists report online April 5 in *Science Express* that the Venus Express spacecraft detected magnetic reconnection in Venus' atmosphere, even though the planet doesn't have an intrinsic magnetic field and thus the effect wasn't expected. — L. K.

25 years ago in *Astronomy*

August 1987

In the August 1987 issue, Joseph A. Lovece outlined a looming threat in "The Impending Crisis of Space Debris." He began with a collision between a "marble-sized piece of metal" and an orbiting telescope that destroys the instrument. "The space around our planet is polluted," Lovece wrote, and while that collision hadn't happened yet, it easily could. Of particular concern was the then-upcoming Hubble Space Telescope, a billion-dollar mission that faced a 1 percent chance of total destruction from space debris.

Nowadays, of course, the problem has gotten worse and poses an even greater danger: The International Space Station must occasionally adjust its orbit to avoid potential collisions. Space debris hasn't yet caused any catastrophic accidents, but, as Lovece noted, perhaps it's only a matter of time.

10 years ago in *Astronomy*

August 2002

The August 2002 issue featured a showcase of the latest and greatest space images in "Hubble's Grand New Vistas" by *Astronomy* Senior Editor Richard Talcott. "You might think that after 12 years in orbit, the Hubble Space Telescope would be plumb out of surprises," he wrote. "Yet like a child entering adolescence, Hubble stands on the threshold of an extraordinary new phase in its life."

The reason was a servicing mission the previous March, the fourth out of an eventual five for the space telescope. Talcott described the newest instruments aboard Hubble while allowing its most recent breathtaking images to speak for themselves. "As the newly revitalized space telescope prepares to enter its teenage years," Talcott wrote, "we can only guess at what surprises it holds in store." It continues to surprise us, even today. — B. A.

Astroconfidential by Karri Ferron

What is the impact of finding galaxies that recycle star-forming material?

Kate Rubin
Humboldt Postdoctoral Fellow at the Max Planck Institute for Astronomy in Heidelberg, Germany


M. Pössel/HdA

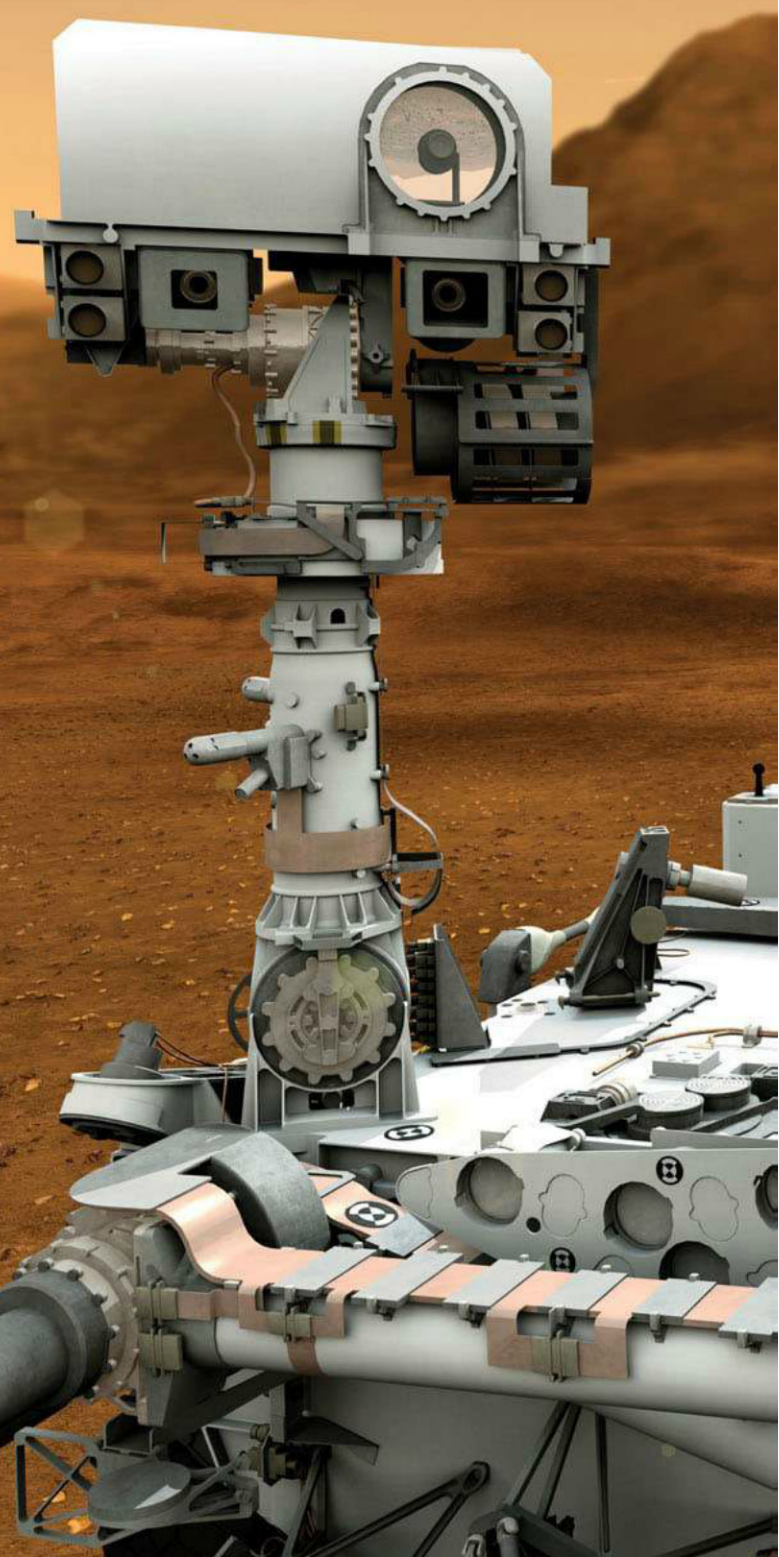
Astronomers have long theorized that galaxies consume gas that falls from intergalactic space into their disks. There, the gas is gradually converted into stars, forming the spectacular galactic structures we observe. This fueling process is fundamental to a galaxy's growth, including that of the Milky Way. Yet for several decades, astronomers have found little direct evidence for this gas infall in the distant universe and even have had trouble accounting for all the fuel needed to maintain our galaxy's current level of star formation.

Within the past year, though, scientists have made great strides in understanding how galaxies are fed. Researchers studying the gas clouds surrounding the Milky Way with the Hubble Space Telescope discovered a new reservoir of material falling onto our galaxy's disk. This material is plentiful enough to supply the missing fuel our galaxy needs to continue its slow growth. At the same time, another research group used Hubble to discover that normal star-forming galaxies like the Milky Way are surrounded by massive amounts of gaseous material that has been enriched with the debris produced during the explosive deaths of stars. Some of this material is so distant that it will never fall back into its host galaxy, but some of it is close enough that it could potentially reenter the galactic disk.

My team's recent Keck observations have finally caught this reentry, or recycling, as it happens, verifying our fundamental understanding of how galaxies grow. And with the next generation of telescopes, we hope to measure the amount and enrichment of gas feeding galaxies as they evolve from 2 billion years after the Big Bang until today, showing just how important gas recycling is to the life cycle of galaxies.

Will Curiosity find

NASA's Mars Science Laboratory mission packs the most advanced suite of scientific instruments ever sent to another world. **by Jim Bell**

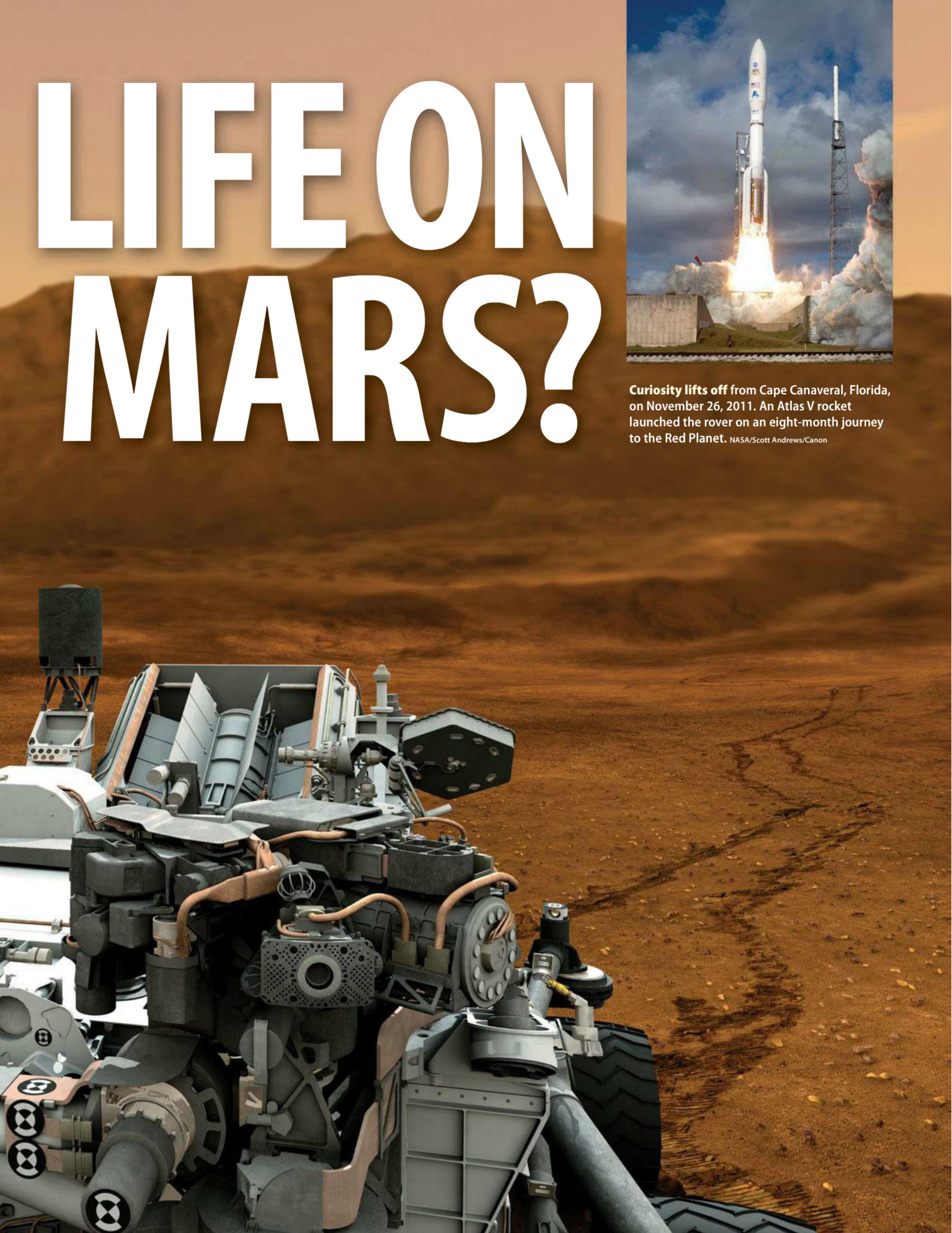


If all goes as planned, earthlings once again will invade Mars sometime during the wee hours of August 6. Or, more accurately, a robotic emissary sent from Earth will invade the Red Planet in an attempt to solve some of the mysteries still held close by our planetary neighbor. The Mars Science Laboratory is the largest, most adept, and most expensive mission to explore Mars. In fact, its suite of scientific instruments and mechanical systems are the most advanced ever sent to another world.

As the spacecraft descends through the planet's ruddy, dusty skies that day to a landing site in Gale Crater, it will be loaded — quite literally — with curiosity. Indeed, "Curiosity" is the name of the rover more formally known as the Mars Science Laboratory. NASA designed this latest martian robot as a follow-on to the space agency's enormously successful twin Mars Exploration Rovers, Spirit and Opportunity, which landed in January 2004. But Curiosity is much bigger and far more capable — a car-sized mobile science lab intended to let mission scientists drive farther and make more-detailed measurements than any previous Mars rover.

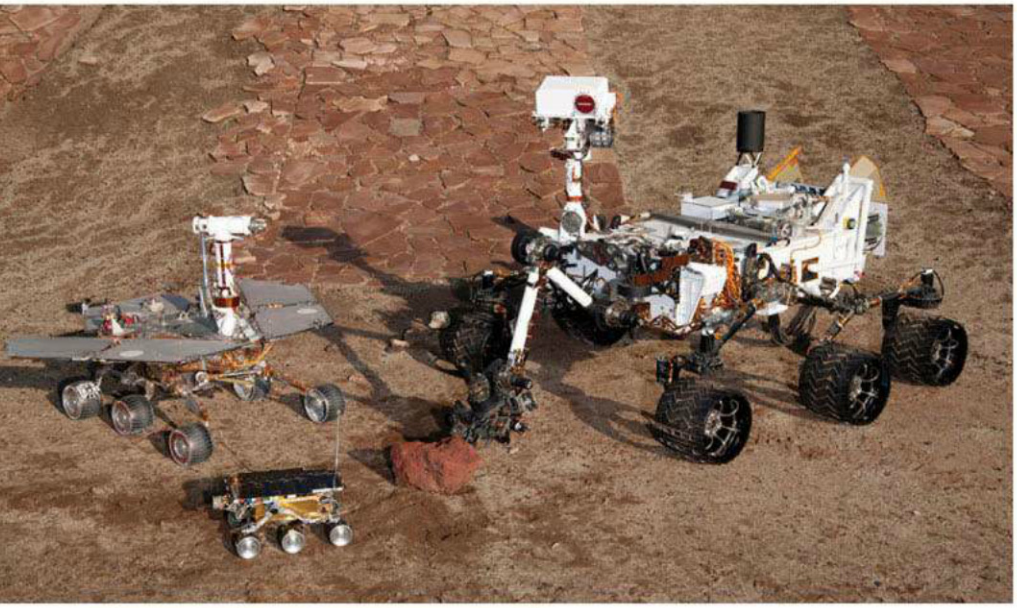
While NASA designed Spirit, Opportunity, and Sojourner (the rover on the 1997 Mars Pathfinder mission) primarily as robotic field geologists, mission

Curiosity explores the floor of Gale Crater in this artist's concept. The rover's mast rises some 7.2 feet (2.2 meters) above the martian surface. The ChemCam instrument for determining rock and soil composition rests at the mast's top while the two "eyes" of Mastcam sit just below it. NASA/JPL-Caltech



LIFE ON MARS?

Curiosity lifts off from Cape Canaveral, Florida, on November 26, 2011. An Atlas V rocket launched the rover on an eight-month journey to the Red Planet. NASA/Scott Andrews/Canon



NASA/JPL-Caltech

Curiosity towers over **its predecessors in the "Mars Yard" testing area at NASA's Jet Propulsion Laboratory in Pasadena, California. The flight spare for the first Mars rover, Sojourner (front), measures 26 inches (65 centimeters) long. A working test model of Spirit and Opportunity (back left) spans 5.2 feet (1.6 meters) while Curiosity's test rover (right) is 10 feet (3m) long.**

Emily Lakdawalla/The Planetary Society

The Curiosity rover **sits in a clean room at NASA's Jet Propulsion Laboratory in Pasadena, California, on April 4, 2011. The rover's mast stands tall while the robot arm is partially extended at left.**

planners built Curiosity as a robotic field astrobiologist. It is endowed with sophisticated instruments optimized to achieve the mission's primary science goal: explore Mars as a potential habitat for life, past or present.

Eyes on Mars

Conducting this comprehensive search for signs of life won't be easy, but those of us controlling the rover will have a suite of a dozen science instruments at our disposal. Like the previous rovers, Curiosity has many sets of digital camera "eyes" to help it navigate, avoid hazards, and collect science data. Among the coolest of these is a pair of stereo-capable color science cameras called "Mastcam." Mounted 6.5 feet (2.0 meters) above the surface on the rover's mast, Mastcam will capture full HD-quality photos and movies. The camera will be able to resolve geologic features as small as about 14 inches across from a mile away (22 centimeters from a distance of one kilometer) and as small as 0.02 inch (0.5 millimeter) across in the area right around the rover.

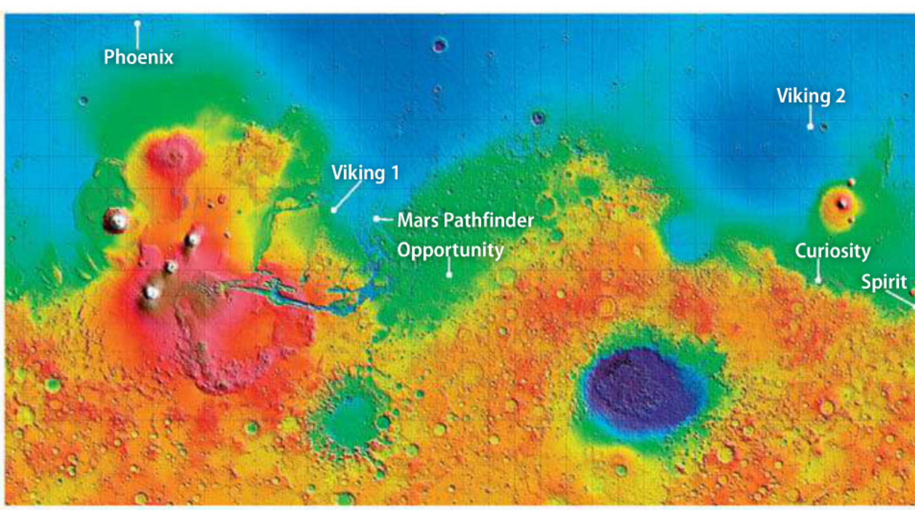
Just as exciting is the Mars Hand Lens Imager (MAHLI), a super-high-resolution color microscope mounted to the rover's robotic arm. MAHLI will resolve structures 50 to 100 micrometers across — about the width of a typical human hair. At this scale, scientists will be able to see evidence of rock and mineral textures, the shapes of embedded grains, and distinctive colors that might provide clues about the area's mineralogy or the past action of water in the region. MAHLI also carries multiple light sources, so it can operate both day and night.

Ken Edgett, the leader of the MAHLI team from Malin Space Science Systems, Inc., in San Diego, California, explains: "When you're out in the field and you want to get a quick idea what minerals are in a rock, you pick up the rock in one hand and hold your hand lens in the other. You look through the lens at the colors, the crystals, and the features that help you diagnose what minerals you see."

Besides Mastcam and MAHLI, Curiosity has eight other onboard camera systems. These will help the science team drive the rover, position the robotic arm, point the chemical-analysis instruments, and take what should be a spectacular movie of the landing site and its surroundings while the spacecraft makes its descent to the surface.

Using its other senses

The rover carries more than just cameras, however. Curiosity is endowed with what some of us on the team lovingly refer to as "squiggly line" instruments because they will make observations that often need to be displayed as lines on a graph or chart. For example, the Alpha Particle X-ray Spectrometer (APXS) will create squiggly line data that reveal the elemental chemistry of the samples it comes in contact with. The Chemistry & Mineralogy (CheMin) instrument also will use X-rays to identify chemical elements as well as the mineral structure of its samples. And the Chemistry & Camera (ChemCam) instrument will use a laser



Gale Crater, **the target of NASA's Curiosity rover, lies just south of the martian equator. The probe will explore an area unlike any visited by the six previous landers and perhaps discover evidence for past or present life. This map shows all of Mars between 70° north and south latitudes.** MOLA Science Team

beam to zap and vaporize rocks and soil up to 23 feet (7m) away and then analyze their elemental chemistry without needing to be in contact with the samples.

Perhaps the most scientifically exciting of the squiggly line instruments, though, is the Sample Analysis at Mars (SAM) suite. These three miniaturized laboratory instruments will perform the most detailed search yet for organic molecules on Mars. If there is methane in the atmosphere, for example, SAM will be able to detect it. Some astronomers think methane formed geologically, but others suspect it to be a byproduct of microbial life beneath the martian surface. Even if there is no life on the surface of Mars today, SAM still could detect certain kinds of chemical-isotope signatures or organic-molecule remnants that might tell mission scientists that life existed on Mars long ago.

A significant part of Curiosity's payload includes a complex system to collect and deliver samples to these other instruments. A drill, a brush, a scoop, and sieves work together to gather carefully selected rock and soil fragments and get them safely into the SAM and CheMin devices deep inside the rover's body.

Curiosity also brings to Mars a weather station, a radiation monitor to assess conditions for future human exploration, and a neutron detector designed to search for evidence of water or ice in the martian subsurface or trapped within minerals at the surface. Overall, it's an extraordinary set of capabilities for both remote and close-up science investigations of the materials the rover will encounter once on Mars.

Curiosity may drive into this filled channel on the edge of Gale Crater's central mound. The color variations here mostly reflect differing amounts of loose dark sediment. NASA/JPL-Caltech/University of Arizona

A site for sore eyes

To get the most out of these scientific observations, NASA needed to find the right landing spot for Curiosity. It wasn't easy. Mission scientists didn't want to end up at a scientifically boring site, the fate of the twin Viking landers in the mid-1970s. Fortunately, our team had far more information about Mars to work with than the Viking scientists had. During the past 15 years, an armada of four orbiters, two landers, and three rovers returned images of Mars and data about its composition that have revolutionized scientists' understanding of this most Earth-like of planetary neighbors.

About six years ago, NASA asked several hundred scientists who study Mars to propose possible landing sites for Curiosity. The locations had to be not only where the rover could touch down safely, but also places where the mission could address its geologic, geochemical, atmospheric, and especially biologic science objectives.

The scientists responded with dozens of spectacular suggestions. Potential sites included some near water-formed gullies, ancient streambeds, and river deltas, others where glaciers once flowed, and many in craters and valleys that boast mineralogically interesting deposits of layered sediments. Most of the proposed sites showed evidence for intriguing mineral signatures as well as exciting geologic landforms, helping to keep the squiggly line scientists just as interested as the photogeologists.

But science wasn't the only deciding factor. NASA eliminated many sites because the presence of steep slopes, abundant large rocks, or loose sand posed too much danger to prospects for a successful landing. And although spots near the large martian volcanoes might have been exhilarating, they didn't pass muster because the rover's landing parachutes wouldn't work properly in the thin air at those high elevations.

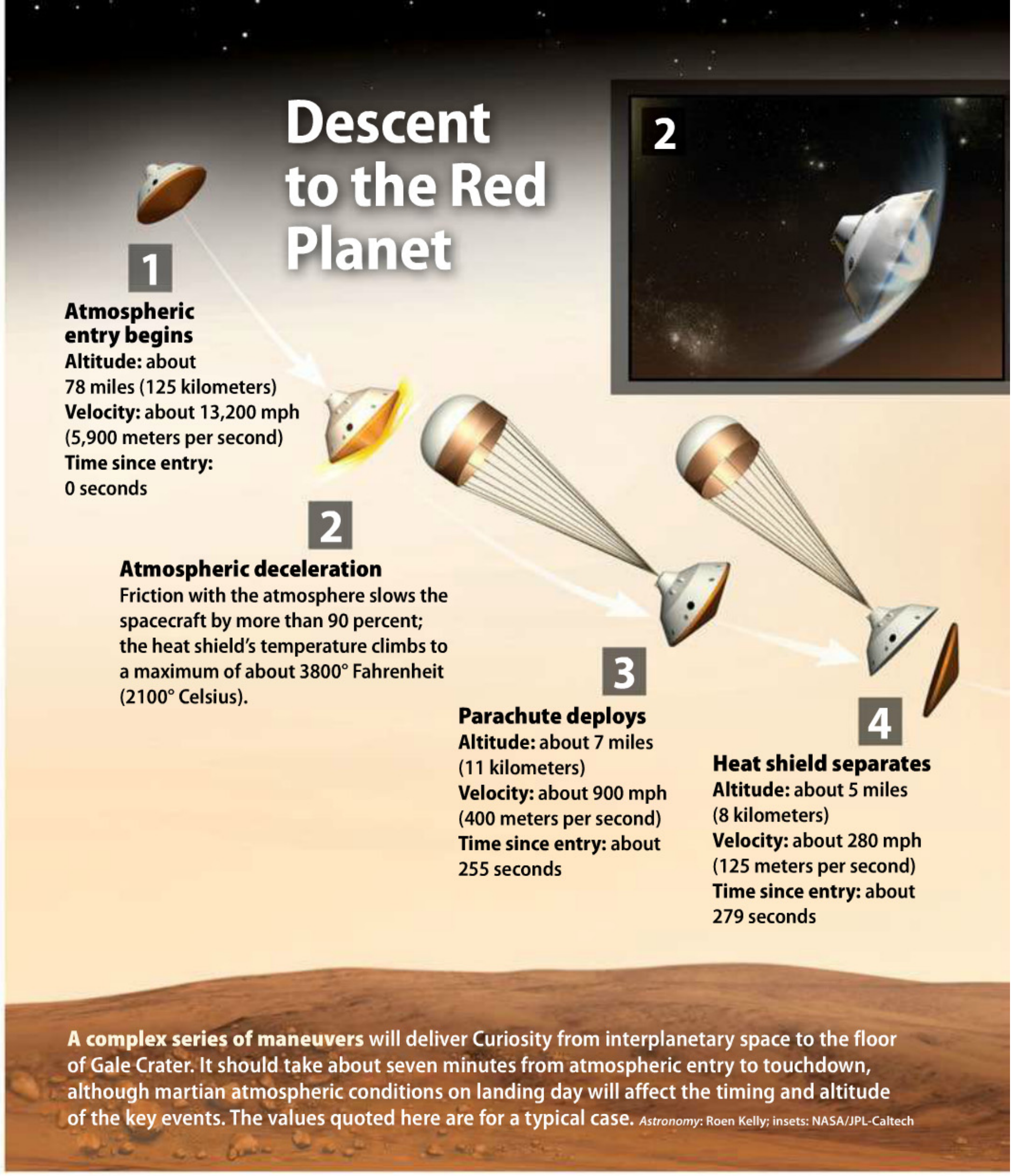
Other possible sites fell victim to the frigid martian nights. The extreme cold places limits on how far from the equator

Curiosity will land somewhere within the ellipse shown on the floor of the 96-mile-wide (154 kilometers) Gale Crater. After coming to rest in this relatively smooth, flat area, the rover will drive toward the large mound at the crater's center. NASA/JPL-Caltech/ESA/DLR/FU Berlin/MSSS

Jim Bell *is a planetary scientist, author, and professor in the School of Earth and Space Exploration at Arizona State University in Tempe. He is a member of the Curiosity rover's camera team, and since 2004 also has been the lead scientist for the Pancam color cameras on NASA's Spirit and Opportunity rovers. Bell's photo-rich space books include* Postcards from Mars, Mars 3-D, *and* Moon 3-D.

Curiosity could land. Although the rover will generate electricity through the radioactive decay of plutonium, like the Viking landers did, it has to devote a lot of power to run the heaters that keep the instruments and systems alive. The solar-panel technology employed by Sojourner, Spirit, and Opportunity simply can't supply enough energy to the far bigger Curiosity rover.

Sometimes it seemed like there was a battle going on between the scientists, who wanted to land Curiosity at a geologically and mineralogically interesting site — which often meant dramatic, potentially dangerous terrain — and the engineers and managers, who sought a flat, boring site to maximize the chances of a safe landing. It was a friendly battle, however, because everyone knew the same basic truth: If the rover didn't survive the landing, we'd get zero science.



A complex series of maneuvers will deliver Curiosity from interplanetary space to the floor of Gale Crater. It should take about seven minutes from atmospheric entry to touchdown, although martian atmospheric conditions on landing day will affect the timing and altitude of the key events. The values quoted here are for a typical case. *Astronomy*: Roen Kelly; insets: NASA/JPL-Caltech

All hail Gale Crater!

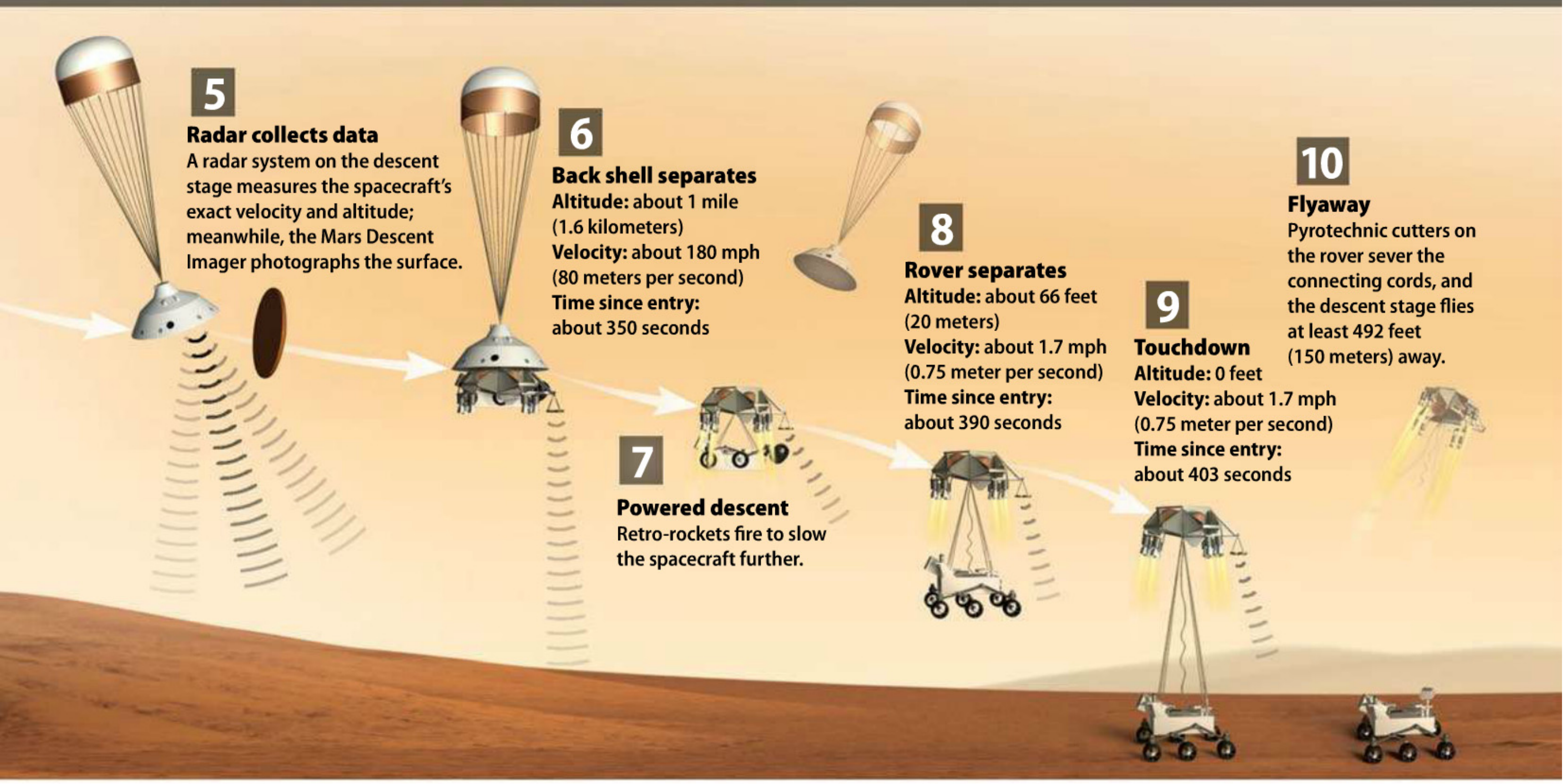
After five years of often contentious meetings and debates, the scientists and engineers found a solution that should make both groups happy. Curiosity is set to land in Gale Crater. An ancient asteroid impact gouged out this deep, 96-mile-wide (154km) hole in the ground, which lies just 5° south of the martian equator.

Even better, Gale Crater happens to have a 3-mile-high (5km) mountain of layered sedimentary rocks within it. The layered rocks in this central mound appear to span a period of Mars geologic time from the oldest epoch, when the planet was much warmer and wetter, to the middle epoch, when the planet began drying out, to modern-day deposits of dust that fall out of the atmosphere at the highest elevations. Gale's mound, nicknamed Mount Sharp, and its surroundings also show mineral signatures that indicate liquid water was once present. At the least, this water coursed through surface streams that carved giant canyons into the mound. But some scientists think the liquid ponded in an ancient lake almost the size of North America's Lake Ontario.

In addition to the spectacular scenery and diverse mineralogy, one other factor tipped the scales in favor of Gale Crater — part of its floor located approximately 6 miles (10km) from the mound is relatively flat and smooth, and will be a safe place to land the rover. Once Curiosity arrives at this benign and somewhat interesting place on the crater floor, mission controllers will drive the rover to the much juicier geologic and mineral features exposed in the layered mound.

The science team is already excited about visiting this site. Some of the scenery could be reminiscent of the canyons and mesas of the American desert southwest. The rover's traverse into and up the mound will be like taking a geologic field trip through martian history, including times when and places where the environment may have been habitable to life as we know it. Jim Green, director for the Planetary Science Division at NASA Headquarters in Washington, D.C., summarizes Gale's selection in this way: "The site offers a

Curiosity probes a martian rock in this artist's concept. The robot arm holds two instruments: the Alpha Particle X-ray Spectrometer for analyzing composition and the Mars Hand Lens Imager for close-up photography of rock surfaces. NASA/JPL-Caltech



visually dramatic landscape and also great potential for significant science findings."

Floating out of the sky

Engineers at NASA's Jet Propulsion Laboratory in Pasadena, California, started constructing Curiosity in mid-2007, although scientists and engineers from around the world provided many of the instruments and other components. Building a robot that needs to fly to and work on another planet is not an easy task, however, and the team ran into many unexpected technical hurdles and cost overruns. The project missed its first launch opportunity in 2009. The team ultimately finished assembling and testing the nearly $2.3-billion rover in time for its launch from Cape Canaveral in Florida on November 26, 2011.

It has taken a little more than eight months for the spacecraft to cruise from Earth to Mars, but the landing sequence from atmospheric entry to touchdown will last only about seven minutes. Curiosity will use a parachute, retro-rockets, and a "Sky Crane" to settle gently onto the martian surface. Engineers designed the unique landing system to deliver the craft to its target because it is too heavy to use air bags, as the previous rovers did. (See "Descent to the Red Planet" above for landing details.)

The rover will arrive during the early morning hours of August 6 (late night August 5 in Pasadena), when it will be late afternoon at Gale Crater. If all goes well, Curiosity will explore the crater for at least one Mars year (nearly two Earth years), but given NASA's recent success in rover longevity, it could survive much longer.

It is anyone's guess what Curiosity's remote-controlled senses will reveal. Does Gale Crater preserve evidence of past or present martian life among that spectacular pile of possibly water-lain sediments the rover will climb? Some on the team are skeptical while others are optimistic. All we really know is that scientists never will be able to answer the question "Are we alone?" unless they make the effort to search beyond the confines of our home planet. One of the best places astronomers have found to start that search is on the planet right next door, and robots like Curiosity provide a cost-effective way to begin.

Many scientists believe that the search ultimately will prove too complex for robots, and that it will take human explorers on Mars — working in concert with robots — to reveal the planet's biologic history. "Mars is firmly in our sights," says NASA Administrator Charles Bolden. "Curiosity not only will return a wealth of important science data, but it will serve as a precursor mission for human exploration to the Red Planet." It should be quite an adventure.

To see an animation of Curiosity landing on and exploring Mars, visit www.Astronomy.com/toc.

How twin rovers found water

In 2004, NASA landed two robot geologists on Mars, hoping to get 90 days of work out of them. After eight years of exploration, Spirit and Opportunity have deepened our knowledge of the Red Planet.

by Robert Burnham

Nobody expected them to live long. When scientists and engineers designed the Mars Exploration Rovers, 90 days seemed enough to carry out the rovers' prime task — to discover and study rocks and soils holding clues to past water activity. This was in keeping with the theme of NASA's Mars exploration: "Follow the water."

The rovers, named Spirit and Opportunity, were launched in June and July 2003, respectively, and arrived in January 2004. The first to land (on January 4) was Spirit, which targeted Gusev Crater — thought to hold lake bed sediments. Opportunity landed three weeks later at Meridiani Planum, a site that holds the planet's largest hematite deposit — about the size of Oklahoma. Hematite is an iron oxide that nearly always forms with water.

Neither rover carried instruments to detect life directly, but water would be a key ingredient of any place that merited the label "habitable." To outfit the rovers, scientists gave them instruments that amounted to a robotic version of what every geologist carries into the field.

Robert Burnham *is the media relations manager for Arizona State University's Mars Space Flight Facility in Tempe.*

Spirit's and Opportunity's journeys and discoveries have surpassed scientists' expectations. Both explored Mars for years, and one is still going; the rovers achieved their prime task by detecting many lines of evidence that water once existed on the Red Planet.

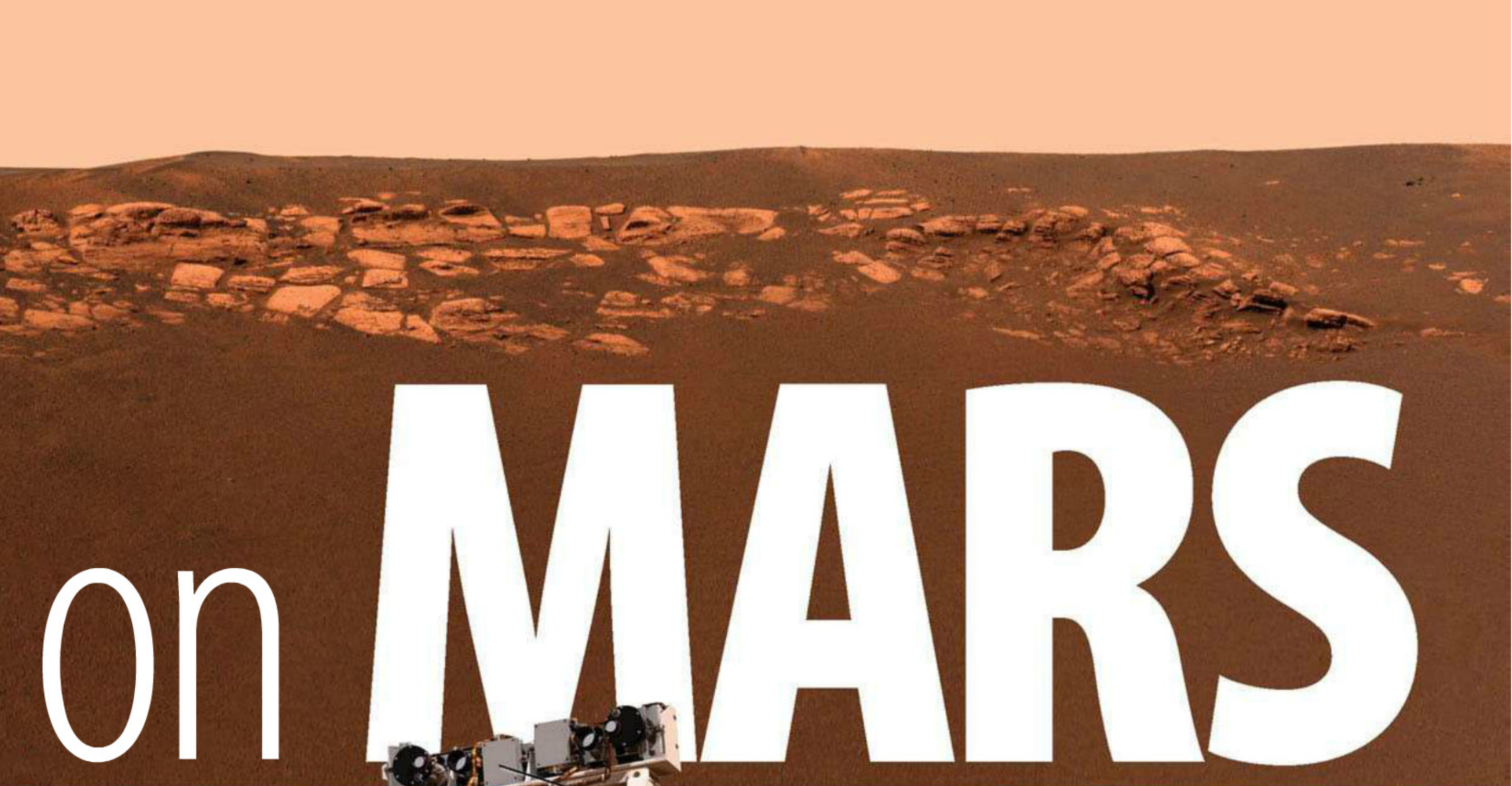
Where to go on Mars?

Meridiani Planum became a high-priority site thanks to the hematite discovery by the Thermal Emission Spectrometer on NASA's Mars Global Surveyor orbiter. Opportunity's Meridiani landing site, a couple of degrees south of the equator, also has light winds and flat ground.

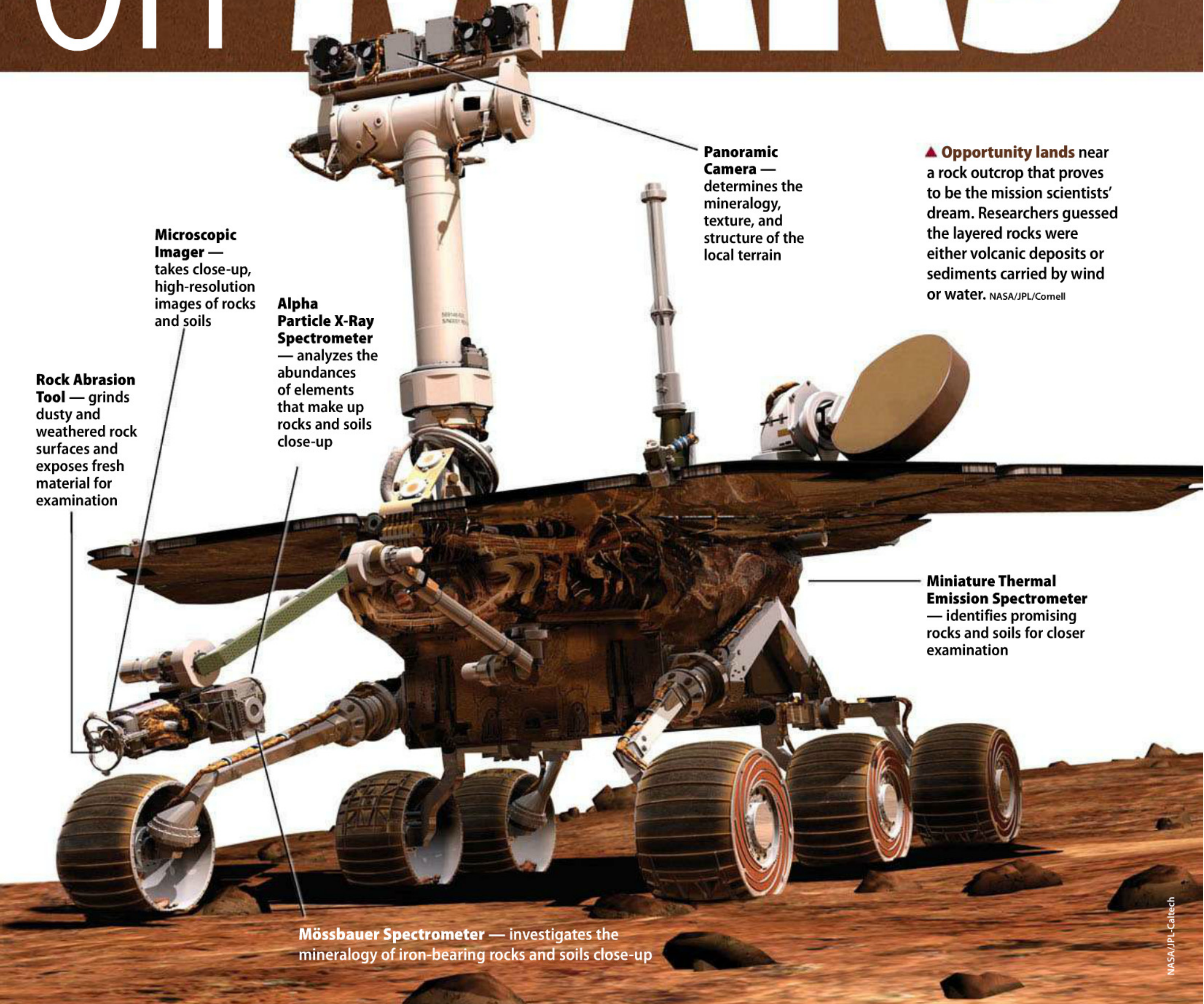
On the other side of Mars and 15° south of the equator, Gusev Crater promised water in a different way. The crater is about 100 miles (160 kilometers) wide and has a mostly flat floor. An ancient river channel, Ma'adim Vallis, meanders down from the highlands to breach Gusev's south rim. Thus, the thinking went, Gusev was a slam-dunk for an ancient crater lake, and Spirit would probably land on lake bed sediments.

The landing went smoothly. Spirit powered up, rolled off the descent stage, and looked around. It saw a smooth, flat landscape with small rocks nearby and enticing hills in the distance under a tawny sky. These were soon

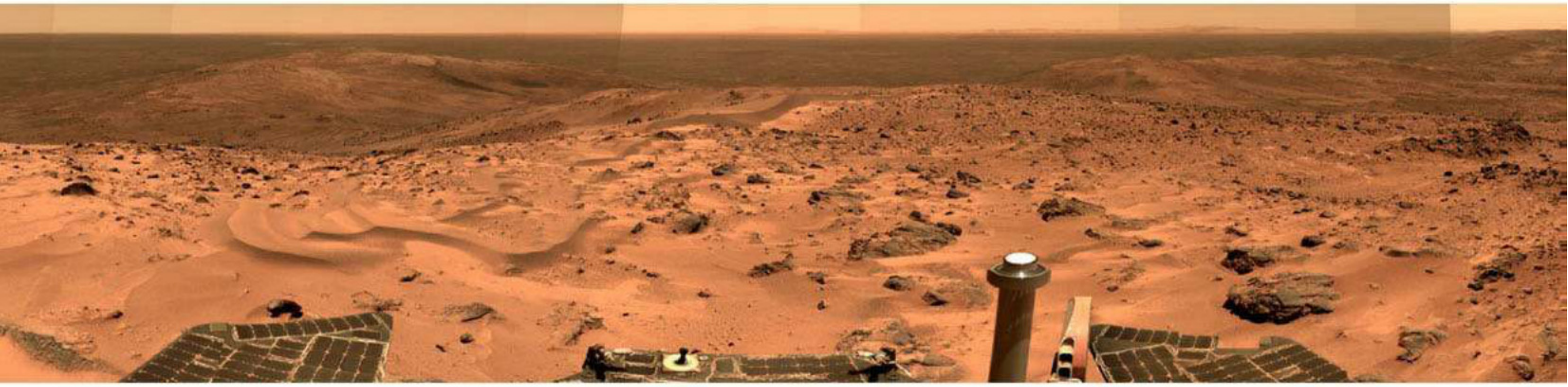
on MARS

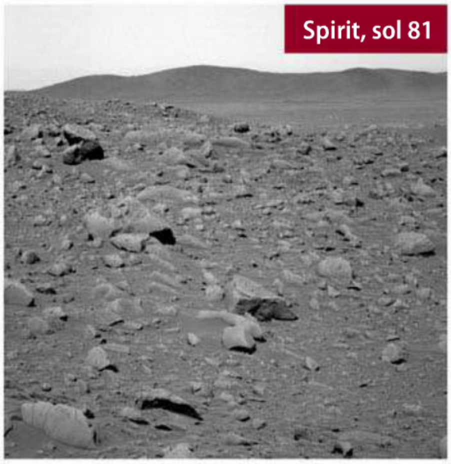


▲ **Opportunity lands** near a rock outcrop that proves to be the mission scientists' dream. Researchers guessed the layered rocks were either volcanic deposits or sediments carried by wind or water. NASA/JPL/Cornell

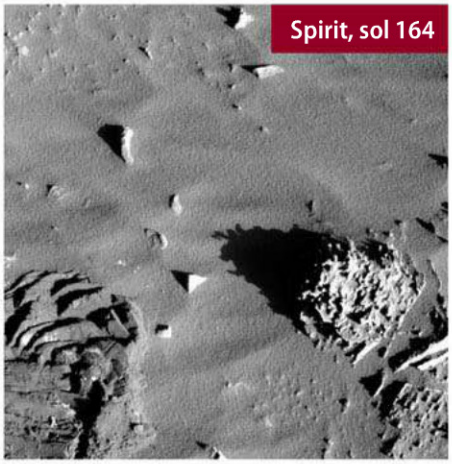


NASA/JPL-Caltech





Spirit's second target, Columbia Hills, lies in the distance. Scientists estimated it would take the rover about 60 sols (martian days) to get there from its imaging position — putting Spirit past its nominal mission length of 90 sols. NASA/JPL/Cornell



Nearing twice the original mission's length, Spirit spots an odd-shaped rock, which team members nickname "Pot of Gold." The rock contains hematite, a mineral that usually forms with water. NASA/JPL/Cornell

named the Columbia Hills to honor the astronauts killed in 2003 when the space shuttle *Columbia* broke up.

But three days after Spirit landed, the mission's principal investigator, Steven Squyres of Cornell University in Ithaca, New York, looked at the images and summed up his growing impression, "I don't think we've landed on bare lake bed deposits."

Using the rover's instruments (see illustration on page 27) to study the soil and the closest large rock — named Adirondack — reinforced his conclusion. As far as cameras could see, dusty rocks made of volcanic basalt covered the plain. Lake sediments, if they existed, were probably buried under lava flows.

As mission control learned how to drive the rover through boulder fields, scientists' attention shifted to the other side of Mars.

Opportunity touched down there 21 days after Spirit (January 25). When scientists turned on the rover's cameras, they were astonished and delighted to find it sitting in a shallow crater with bedrock directly ahead. Better still, the outcrop, nearly a foot high, appeared to have layers like sedimentary rock and was lighter in color than basalt. The rover's Miniature Thermal Emission Spectrometer (Mini-TES) mineral scouting instrument showed that the Meridiani landscape is loaded with hematite.

It amounted to an interplanetary hole in one: Opportunity came to rest directly upon the water-altered material it was sent to find. Primary science goal achieved, and the rover had barely set a wheel on Mars.

Spirit: head for the Hills

Over in Gusev, team Spirit was struggling. So, Squyres gave the rover's crew a new target, a time line, and a change in operational style: Put science on the back burner, he said, and get Spirit to the Columbia Hills by sol 160, its 160th day on Mars. (The martian day rhymes with "awl," and it runs 39 minutes longer than Earth's day.)

With a distance of 1.7 miles (2.7km) to cover, Spirit would have to make an average run of 66 yards (60 meters) every sol.

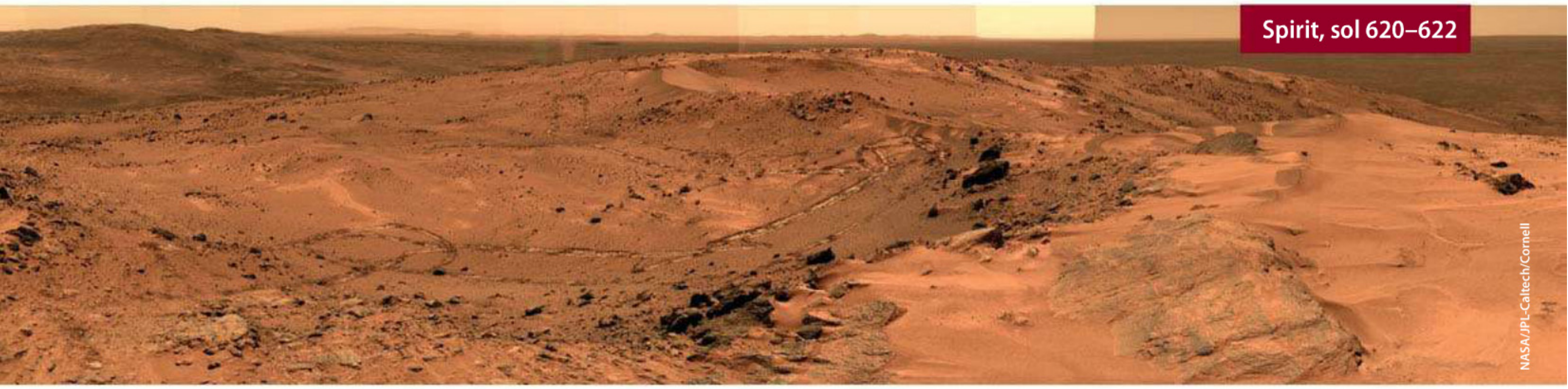
Opportunity: seek sediments

As Spirit chugged toward the Columbia Hills, Opportunity explored its first outcrop. Seen by the rover's Microscopic Imager and other instruments, the rocks showed textures that revealed its sand-sized sediments were laid down in moving water about a foot deep. The sediments proved rich in sulfur, chlorine, and bromine, which showed that water had repeatedly dried up and then returned. The biggest surprise was finding jarosite, an iron-bearing sulfate rock uncommon on Earth.

Mini-TES spotted hematite all around the rover, and the cameras showed uncountable small spherules a few millimeters in diameter littering the ground. The Mössbauer Spectrometer, which determines the composition of iron-bearing minerals, clinched the connection: These "blueberries" (named for their size) are hematite-rich. They had formed within the outcrop rock as concretions by a chemical process similar to how an oyster turns grit into a pearl. And being tougher than the rock, the blueberries eroded more slowly, leaving them to cover the surface.

NASA/JPL-Caltech/Cornell University

Soft soil partially buries Spirit's wheel, leaving the rover unable to move. This same location is where the rover would send its last communication to Earth on March 22, 2010.



▲ **Atop the summit** of Husband Hill, Spirit captures this panorama. As more than 150 martian days pass, the rover inches upward along the north side of Husband Hill — some 270 feet (82 meters) above the Gusev plain.

With that, it was time (sol 58) for Opportunity to hit the road. About 2,300 feet (700m) to the east lay a stadium-sized crater named Endurance, 430 feet (130m) wide and 70 feet (20m) deep. Inside, scientists hoped to see a much larger section of sediments than in the crater where Opportunity landed. Opportunity reached the edge of Endurance on sol 95 and peered in.

The rim and upper walls showed steep layers of sedimentary rocks; in the bottom were wind-sculpted dunes. Falling from the cliffs could easily destroy the rover, and the sand was no-go terrain. "We're going to have to be very careful here," thought Squyres. Yet in part of the rim, an area dubbed Karatepe, the crater's interior offered rocky pavement that sloped only about 20° — trafficable with careful driving.

On sol 133, Opportunity took its first rolling step into Endurance.

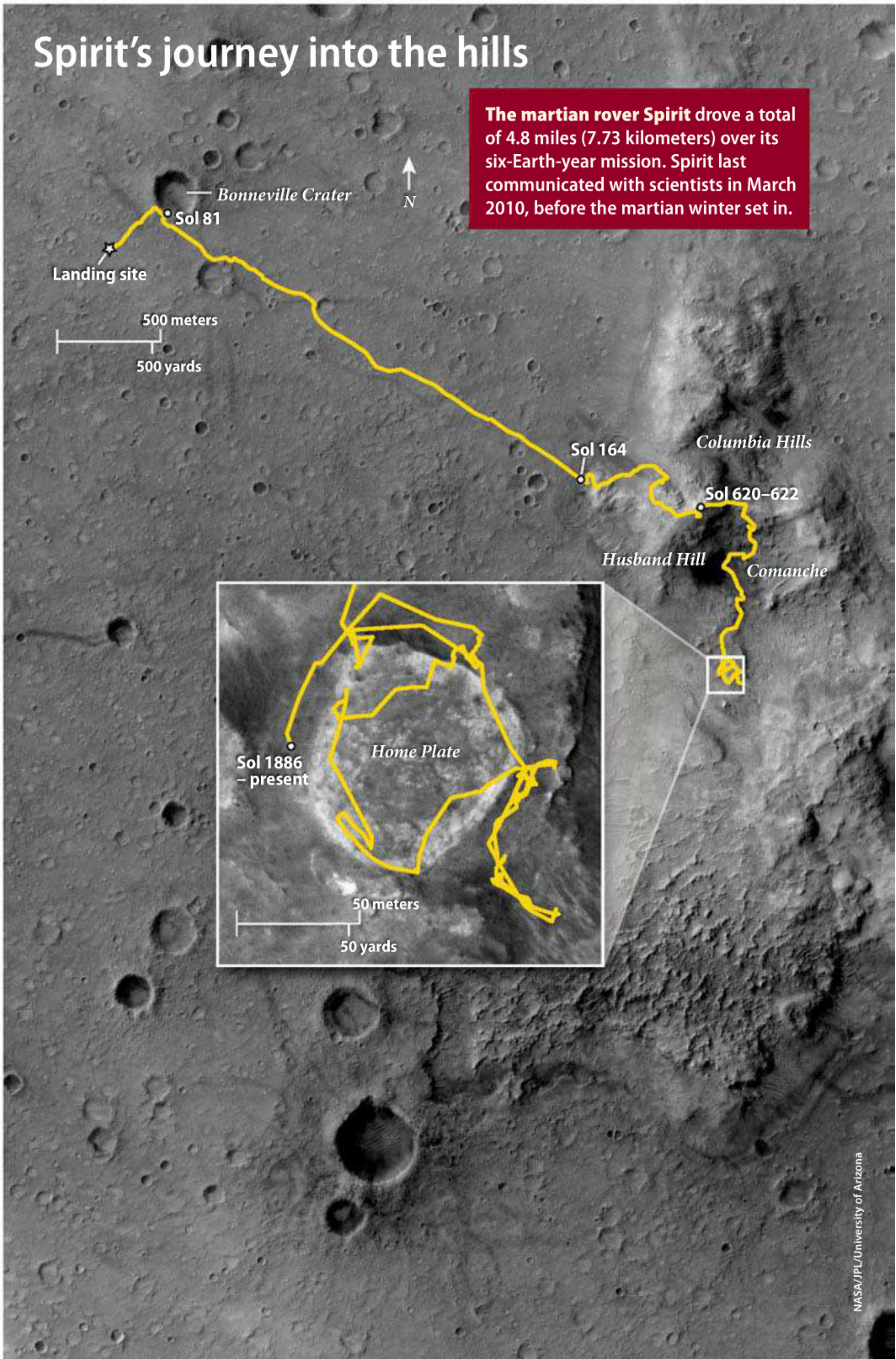
Spirit: odd rocks

Spirit reached West Spur, an outlier of the Columbia Hills, on sol 159. Immediately, the rocks became interesting.

Scientists gave the moniker Pot of Gold to the strangest rock any team geologist had seen. The size of a softball, it has little nodules "like somebody took a potato and stuck toothpicks in it, then put jelly beans on the ends of the toothpicks," as Squyres describes it. And Spirit's analytical spectrometers showed Pot of Gold also holds hematite — a first for Spirit and boding well for finding water-altered rocks in the hills.

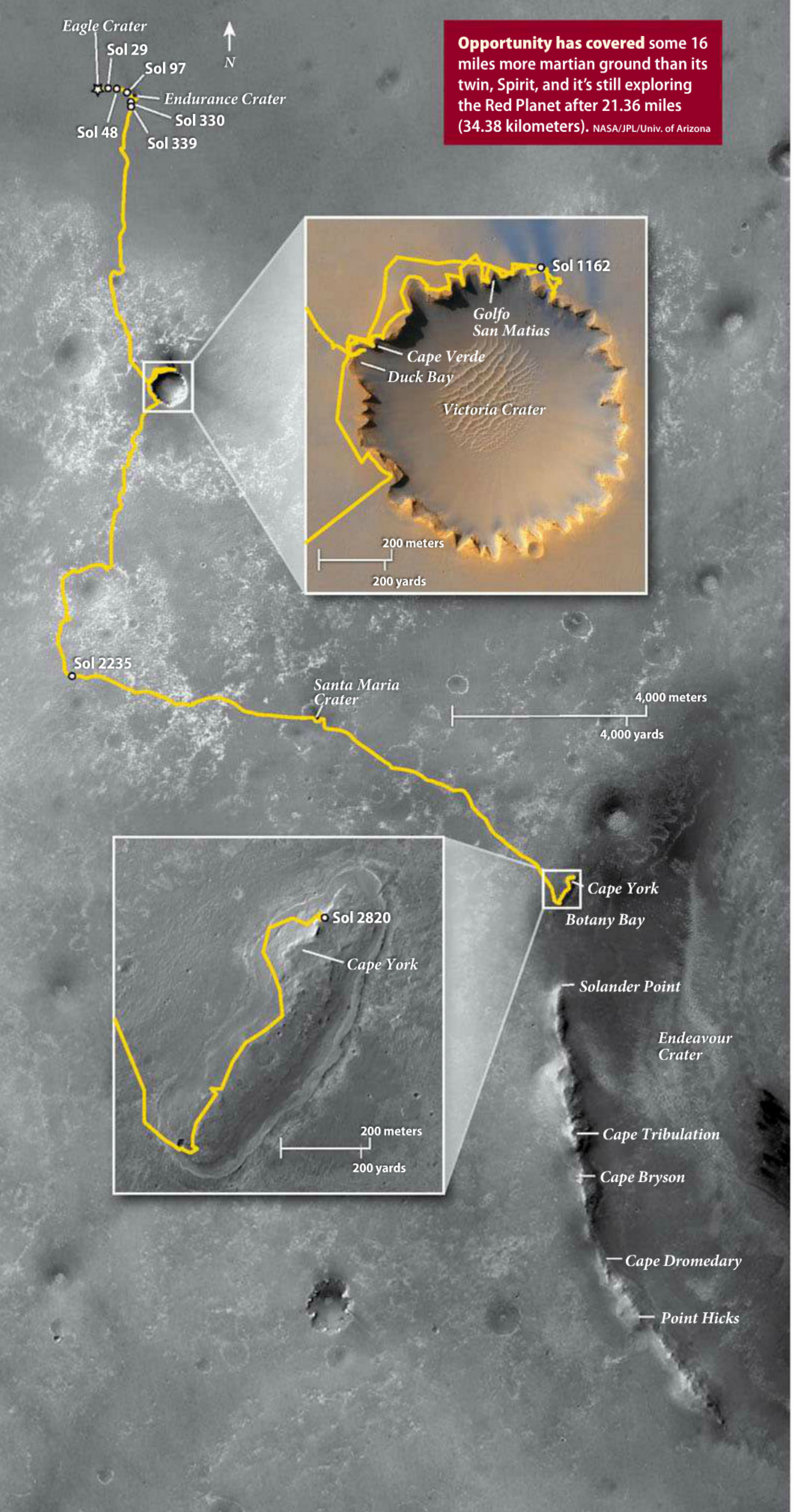
After leaving Pot of Gold, the Spirit team began to deal with a mechanical problem: The right front wheel started drawing about twice as much power as the others.

Spirit's journey into the hills



The martian rover Spirit drove a total of 4.8 miles (7.73 kilometers) over its six-Earth-year mission. Spirit last communicated with scientists in March 2010, before the martian winter set in.

Opportunity's crater tour



Opportunity has covered some 16 miles more martian ground than its twin, Spirit, and it's still exploring the Red Planet after 21.36 miles (34.38 kilometers). NASA/JPL/Univ. of Arizona

Engineers decided to alternate driving the rover facing forward and in reverse in hopes to even out the wear.

By this point, Spirit had lasted twice its nominal mission length. Moreover, the solar panels had collected dust, preventing them from delivering as much power. And finally, martian winter was approaching, with nights getting colder and the Sun daily lower in the north. The rover had power for only an hour or so each day, so engineers drove Spirit slowly into Columbia Hills, keeping it on slopes leaning north toward the Sun.

Finally, on sol 581, Spirit reached Husband Hill's summit. To the southeast was the Inner Basin, a shallow depression nestled between the hills.

Spirit watched as dust devils whirled by on the plains, and a gust of wind must have passed over the rover because one morning it woke up with its panels nearly as clean as the day it landed.

Spirit would descend into the Inner Basin and head for an enigmatic feature dubbed Home Plate. What it was no one knew (maybe lake bed deposits?), but it looked different from everything else in the hills.

Opportunity: deeper history

In Meridiani, mission control placed Opportunity on the north-facing inner slope of Endurance at Karatepe. There, the rover used its Rock Abrasion Tool (RAT) to grind into exposed rocks and then deployed its spectrometers. The results showed that water had been episodically present, with repeated floods followed by dry periods.

The rover's last stop in Endurance was Burns Cliff. Amazingly, Opportunity was able to drive partway up the bottom of the cliff slope. Describing the rocks, the science team reported that the Burns formation is made of sedimentary rocks that a wind-swept, arid surface environment created. Water, they said, rose occasionally to the

The second crater Opportunity visits is Endurance. The rover spends some 200 martian days exploring the floor and exposed walls. NASA/JPL/Cornell

surface, and sulfate-rich sand grains were reworked by the wind to form dunes and sand sheets. The multiple floodings by groundwater changed the rock and formed the hematite-rich blueberries.

On sol 315, Opportunity drove out of Endurance onto the Meridiani plains again. About 4 miles (6km) south lay a crater named Victoria, six times larger than Endurance and more than three times deeper. Scientists hoped to find older layers than those in Endurance — but it would be a long drive, some 18 to 20 months. Opportunity started south on sol 352.

Spirit: rounding Home Plate

Meanwhile, Spirit descended from the top of Husband Hill into the Inner Basin. On sol 697, it arrived at outcrops named Comanche and Comanche Spur. Spirit's instruments studied them, but Comanche's big secret — that it is full of carbonate minerals left by water — didn't emerge until more than four Earth years later.

"Mini-TES got dusted months before Spirit reached Comanche, and at the time we didn't have a good way to correct for it," says Steve Ruff, lead Mini-TES scientist at Arizona State University in Tempe. "We knew there was something weird about the outcrop's spectrum but couldn't say what."

Developing a calibration to remove the effects of the dust took several years, but it did the trick. "Small amounts of carbonates have been detected on Mars before," Ruff explains. But with Comanche, "the rocks are about 25 percent carbonate by weight — by far the highest abundance seen on Mars."

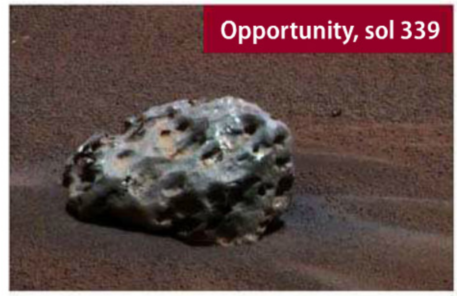
After Comanche, Spirit drove steadily downhill toward Home Plate, a low plateau about 7 feet (2m) high and 260 feet (80m) across. It arrived on sol 746.

On sol 754, Spirit imaged a golf-ball-sized rock sitting in a shallow little crater on the edge of Home Plate. The rock is what geologists call a volcanic bomb, and the mini-crater is the "splat mark" where it landed. This supported the idea that Home Plate might be a hot spring or steam vent. Yellowstone National Park in Wyoming has many such features.

As Spirit headed away from Home Plate, the soil grew softer and harder to drive on. On sol 779, the long-balky wheel stopped turning altogether. Engineers decided to drive Spirit thereafter in reverse, letting the stuck wheel drag.

The upper and lower portions of the rock outcrop "El Capitan" have different textures, so Opportunity uses its Rock Abrasion Tool to sample the soil at both locations. The outcrop is just 4 inches (10 centimeters) tall. NASA/JPL

Hematite "blueberries" scatter across the ground in a rock outcrop near Opportunity's landing site, providing the rover with immediate evidence of past water activity. NASA/JPL/Cornell



NASA/JPL/Cornell

An iron meteorite about the size of a basketball sits on the ground near Opportunity's heat shield. Dubbed "Heat Shield Rock," it is the first meteorite to be identified on another planet.

But the season was advancing. For its second winter on Mars, engineers drove the rover back toward Home Plate and tipped it northward at a site called Low Ridge.

Opportunity: rolling to Victoria

Opportunity's drive south to Victoria Crater would last more than 600 days. The trip was mostly uneventful. Opportunity motored onward, although daily driving periods grew shorter as its solar power dwindled.

Gradually, bits of Victoria's rim poked above the horizon, and Opportunity reached the edge of the 0.5-mile-wide (0.8km) crater on sol 953. Its cameras saw rugged walls with layers of exposed rock nearly 50 feet (15m) high and a floor blanketed with dunes. The rim itself was deeply scalloped into bays and promontories.

The top part of the stack of layers exposed in the walls appeared to be rubble thrown outward by the impact that dug the crater. "We see an abrupt transition between the jumbled-up material and intact layers below it that are still in place from before the impact," says Squyres. "Every promontory has the kinds of layering expected for ancient wind-blown sand deposits." The layers are made of sulfate-rich sandstone similar to the bedrock Opportunity had been seeing since landing on Mars.

Shortly after leaving Endurance Crater, Opportunity pays a call on some terrestrial debris: the wreckage of its heat shield discarded on landing. Engineers want to see how the heat shield withstood the fiery entry into the martian atmosphere. NASA/JPL/Cornell

The rovers' upgraded software allows them to drive around obstacles that they encounter, like this patch of large rocks in Opportunity's path. NASA/JPL-Caltech/Cornell University

But just as Opportunity was about to enter the crater at a location called Duck Bay, a global dust storm cut sunlight to only 1 percent of its normal level. All of Opportunity's activities (Spirit's too) came to a halt until skies cleared about 50 days later.

Spirit: martian Yellowstone?

Spirit stayed parked from sol 805 to 1037. More hot-spring evidence surfaced when the rover drove again. Heading northward up the east side of Home Plate, the stuck wheel dragged a trench. "The trench looked bright white," Ruff recalls, "but we thought initially it was just more sulfate minerals."

He then got curious: "We aimed Mini-TES at the trench and saw a clear silica spectrum. The rover's Alpha Particle X-Ray Spectrometer told us the white soil was more than 90 percent silica. That's a record high for silica on Mars."

Making such pure silica requires a lot of water, says Ruff. "On Earth, the only way to have this kind of silica enrichment is by hot water reacting with rocks" — like at Yellowstone National Park's hot springs.

The find linked the silica with Home Plate, which the rover team already knew to be a volcanic feature. "We saw where rocks were thrown into the air and landed to make small indentations in the soft, wet ash sediment around the vent," says Ruff.

Once alerted about what to look for, the scientists discovered more silica in many places nearby. As Ruff says, "It's not just the soil in a trench in one place. It's a broader story of outcrops that extend 50 meters [160 feet] away from Home Plate. This wasn't a small-scale, modest phenomenon."

The same dust storm that idled Opportunity also put Spirit on hold. After skies cleared, on sol 1309, scientists drove the rover up onto Home Plate, where it slowly toured the perimeter. By the time it reached the plateau's northern edge on sol 1410, controllers had to prepare Spirit for its third winter. It found a location slightly off Home Plate's edge with good northern exposure.

Opportunity: Victoria's secrets

On sol 1292, Opportunity drove into Victoria Crater. "We see evidence from orbit for clay minerals under the layered sulfate materials," says Raymond Arvidson of Washington University in St. Louis, Missouri. "These indicate less acidic conditions. The big picture appears to be a change from a more open hydrological system with rainfall to more arid conditions with groundwater rising to the surface and evaporating, leaving sulfate salts behind."

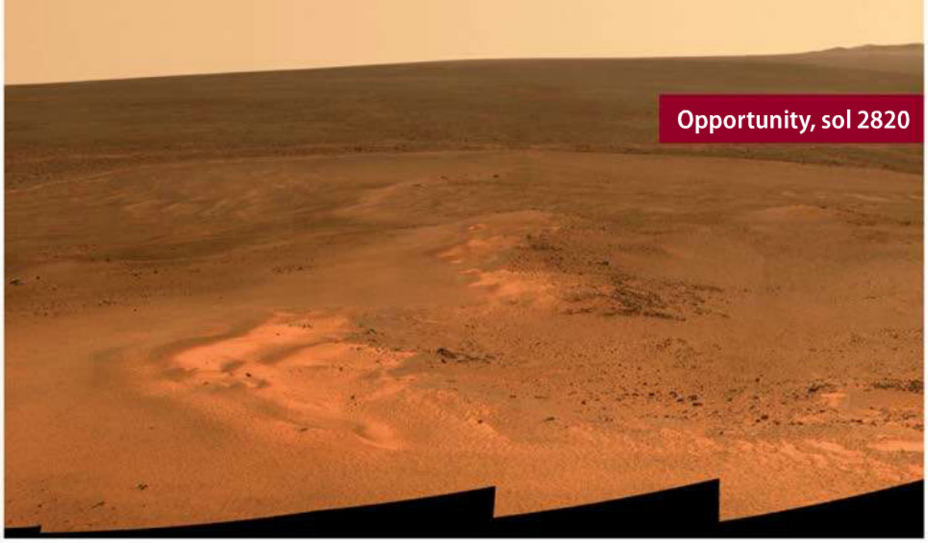
Opportunity examined a bright band of rocks around the inner wall of the crater. Inspection suggested that Victoria was at the top of an underground water table.

Experiments with simulated Mars conditions and computer modeling helped researchers assess whether the long-ago environment at Meridiani would have been hospitable to microbes.

"Life at the martian surface would have been very challenging for the last 4 billion years," says Andrew Knoll from Harvard University in Cambridge, Massachusetts. Conditions may have been more hospitable earlier. "The best hopes for a story of life on Mars are at environments we haven't studied yet — older ones, subsurface ones."

Opportunity's data suggested that the wind deposited the Victoria sediments, and

Opportunity drives along a sand ripple and keeps its solar panels tilted northward to maximize the limited sunshine. NASA/JPL-Caltech



Opportunity celebrates its eight-Earth-year anniversary atop Greeley Haven, an outcrop at Endeavour Crater's rim. The rover has far surpassed the original 90-martian-day mission length and continues to excite mission scientists with its discoveries. NASA/JPL-Caltech/Cornell/Arizona State Univ.

Mars in the raw

You can keep up with Opportunity's trek by seeing the raw images it sends back every few days. Go to http://marsrovers.jpl.nasa.gov/gallery/all/opportunity.html and pick which camera you wish to see. All images are in JPEG format.

The views from the Hazard Cameras (Hazcams) look distorted because they're taken through fisheye lenses. File names are complicated, but there's a link on the page that tells you how to decode them.

Spirit has an identical raw-image page, where you'll see that its last photos (out of 128,224 in all) are from sol 2208 (March 21, 2010): http://marsrovers.jpl.nasa.gov/gallery/all/spirit.html.

Finally, to follow the mission sol by sol, check out: http://marsrovers.jpl.nasa.gov/mission/status.html.

groundwater altered them. "The patterns broadly resemble what we saw at the smaller craters explored earlier," says science team member Scott McLennan of Stony Brook University in New York. "By looking deeper into the layering, we are looking further back in time."

While exploring Victoria, a spike in electric power drawn by the rover's left front wheel resembled one seen on Spirit before its right front wheel failed. Opportunity's six wheels still worked, but the team heeded the warning. If the rover lost the use of a wheel while inside Victoria, it would probably be stuck in the crater forever. Once on flat ground, however, five wheels would suffice to keep it going.

Spirit: winter's icy hand

Spirit's third winter lasted from sol 1410 to sol 1760. With the rover's solar panels dusty and the Sun low, Spirit generated enough power to keep alive, but its science activities were rationed. When spring came, Spirit was no longer able to climb up on Home Plate. So engineers turned the rover west.

On sol 1870, Spirit reached a site named Troy and positioned itself to go up a low ramp on the south side of Home Plate. But on the next day's drive, the wheels on one side of the rover sank into the soil of a small crater named Scamander, and the rover stopped. Drive attempts on following days merely embedded Spirit's wheels ever more deeply in the soft ground.

Spirit remains at Scamander today.

Mission engineers spent 10 months trying to free the rover, but they labored in vain. On sol 2156, NASA changed Spirit's mission: Scientists would track its radio signals to detect tiny wobbles in Mars' rotation, a task impossible with a mobile rover. The data would yield insight about the planet's core.

On sol 2210 (March 22, 2010), Spirit reported that it was operating normally under its master control program, and all systems were "green." But its next downlink, scheduled for eight days later, never came.

Engineers anticipated that as sunlight and power strengthened in spring 2010, the rover would awaken and re-establish communication with Earth.

But Spirit never woke up.

Opportunity: the big road trip

On sol 1622, after a year spent exploring Victoria from the rim and another year inside, Opportunity was back out on the plains and on its way to Endeavour Crater, approximately 7 miles (12km) to the southeast. Endeavour is huge — 14 miles (22km) wide — and rising above the Meridiani plains are old rim segments, which are the crater's main attraction for scientists. As a bonus, clay minerals, which form exclusively under wet conditions, were spotted from orbit in parts of Endeavour's rim.

The great trek began on sol 1682 (October 17, 2008). Around sol 2260, Opportunity turned southeast on a more direct route to Endeavour. As it drove, the rover studied eroded craters, including Santa Maria (295 feet [90m] wide), and discovered several meteorites.

Finally, on August 9, 2011, which was sol 2680 of the rover's original 90-sol mission, Opportunity arrived at Cape York, Endeavour's nearest rim segment. Since it landed back in January 2004, Opportunity had driven 20.81 miles (33.49km).

The rim rocks at Endeavour are impact deposits from the Noachian period some 4 billion years ago, and are older and completely different in type from the flat sediments that Opportunity had driven on for the previous eight years. In a real sense, a new rover mission began at Endeavour.

By any measure, Opportunity is now a senior citizen. The radioactive cobalt-57 source in its Mössbauer Spectrometer has decayed in strength to the point where measurements that took an hour when the rover landed now take a month. The RAT still has some grinding left, and the cameras all work fine. But the instrument arm has a frozen joint, the wheel drivers show wear, and the solar panels are dusty. Mini-TES, which would be invaluable among the varied rim rocks at Endeavour, stopped working on the trip from Victoria.

So what's Opportunity's future? On sol 2947 (May 8, 2012), it drove down from Greeley Haven, its winter parking spot, to study a patch of nearby dust. Opportunity will drive south along the inner slope of Cape York, heading for Cape Tribulation, the next large rim segment. Among other things, it'll hunt for those clay minerals glimpsed from orbit.

But whether Opportunity's future is long or short, it will continue to take us along on its incredible journey, across a beautiful and desolate planet.

Visit www.Astronomy.com/toc to learn about the meteorites the rovers found.

How we'll get to Mars

Landing humans on the Red Planet will be difficult and dangerous — but it can be done. **by Richard Talcott; illustrations by Roen Kelly**

WHEN NEIL ARMSTRONG STEPPED on the Moon's dusty gray surface July 20, 1969, it was the heart-stopping culmination of a decadelong rush to send people to our next-door neighbor. In the more than 40 years since, the human exploration of the solar system has proceeded at a decidedly slower pace.

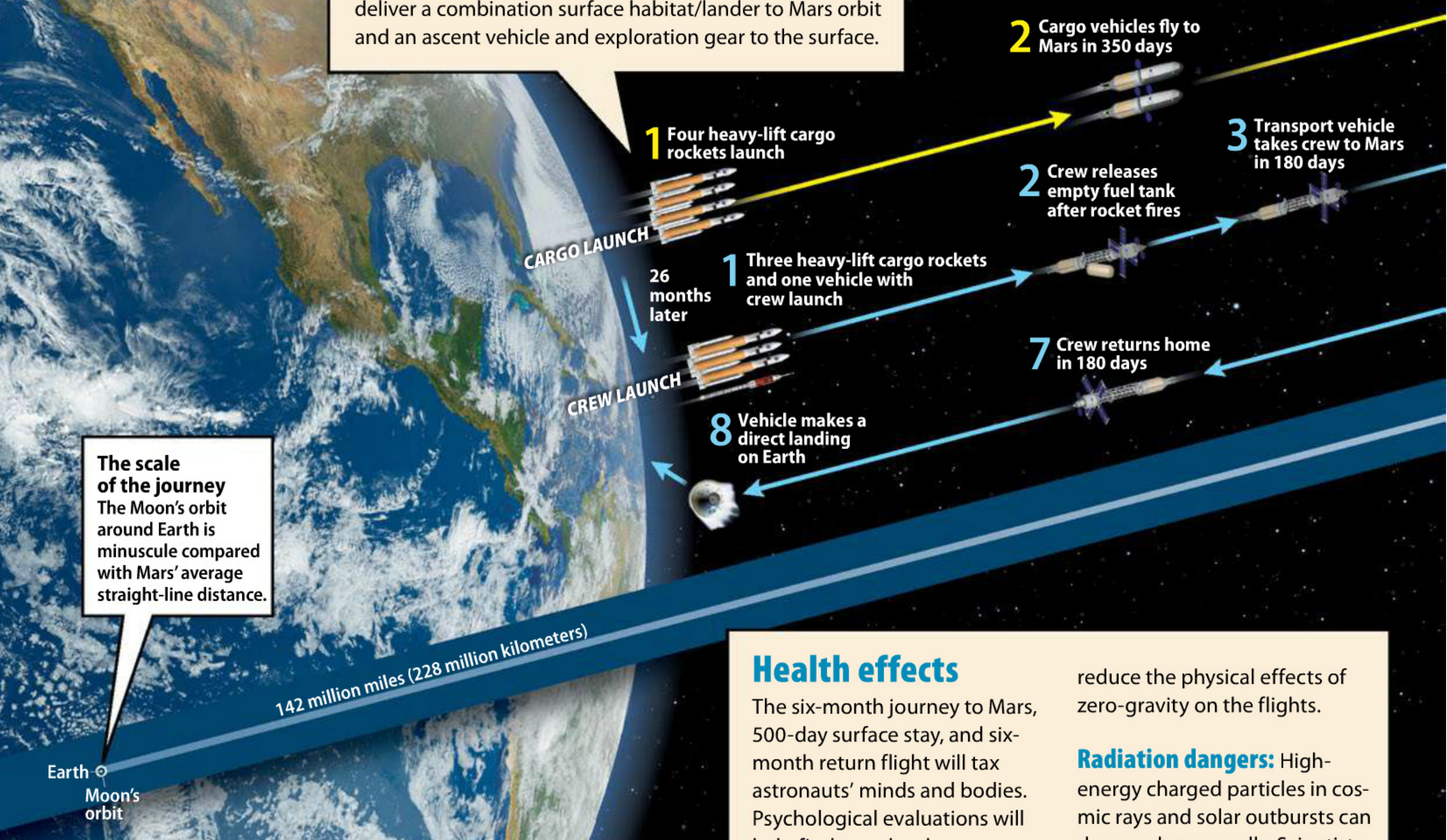
Mars has all the qualities a spacefaring nation or nations could want for the next destination. The Red Planet lies relatively close to Earth, so the journey can be completed in a reasonable period, and it possesses a fairly benign environment.

The Mars Design Reference Architecture 5.0 described here is NASA's most recent outline for such a mission. Although the plan may change before the space agency implements it, the overall framework likely will look similar whether the United States, some other country, or an international effort ultimately achieves the goal.

Richard Talcott *is an* Astronomy *senior editor and author of* Teach Yourself Visually Astronomy *(Wiley Publishing, 2008).*

Cargo shipment

Some 26 months before the crew launches, heavy-lift cargo vehicles will carry equipment to Mars. They will deliver a combination surface habitat/lander to Mars orbit and an ascent vehicle and exploration gear to the surface.



The scale of the journey
The Moon's orbit around Earth is minuscule compared with Mars' average straight-line distance.

Health effects

The six-month journey to Mars, 500-day surface stay, and six-month return flight will tax astronauts' minds and bodies. Psychological evaluations will help find people who can cope with extended isolation, while strict exercise programs will reduce the physical effects of zero-gravity on the flights.

Radiation dangers: High-energy charged particles in cosmic rays and solar outbursts can damage human cells. Scientists don't yet have a good understanding of the potential risks.

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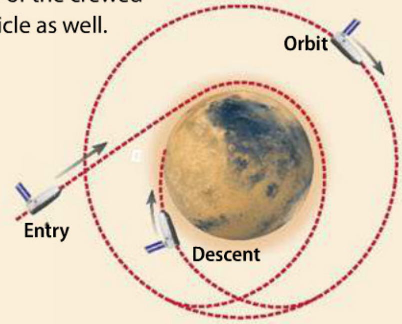
Aerocapture

Mission designers will use Mars' atmosphere to slow the massive cargo spacecraft enough for the planet's gravity to capture them into orbit. Rocket firings will then lower vehicles to the surface. Current plans call for aerocapture of the crewed vehicle as well.



Landing strategy

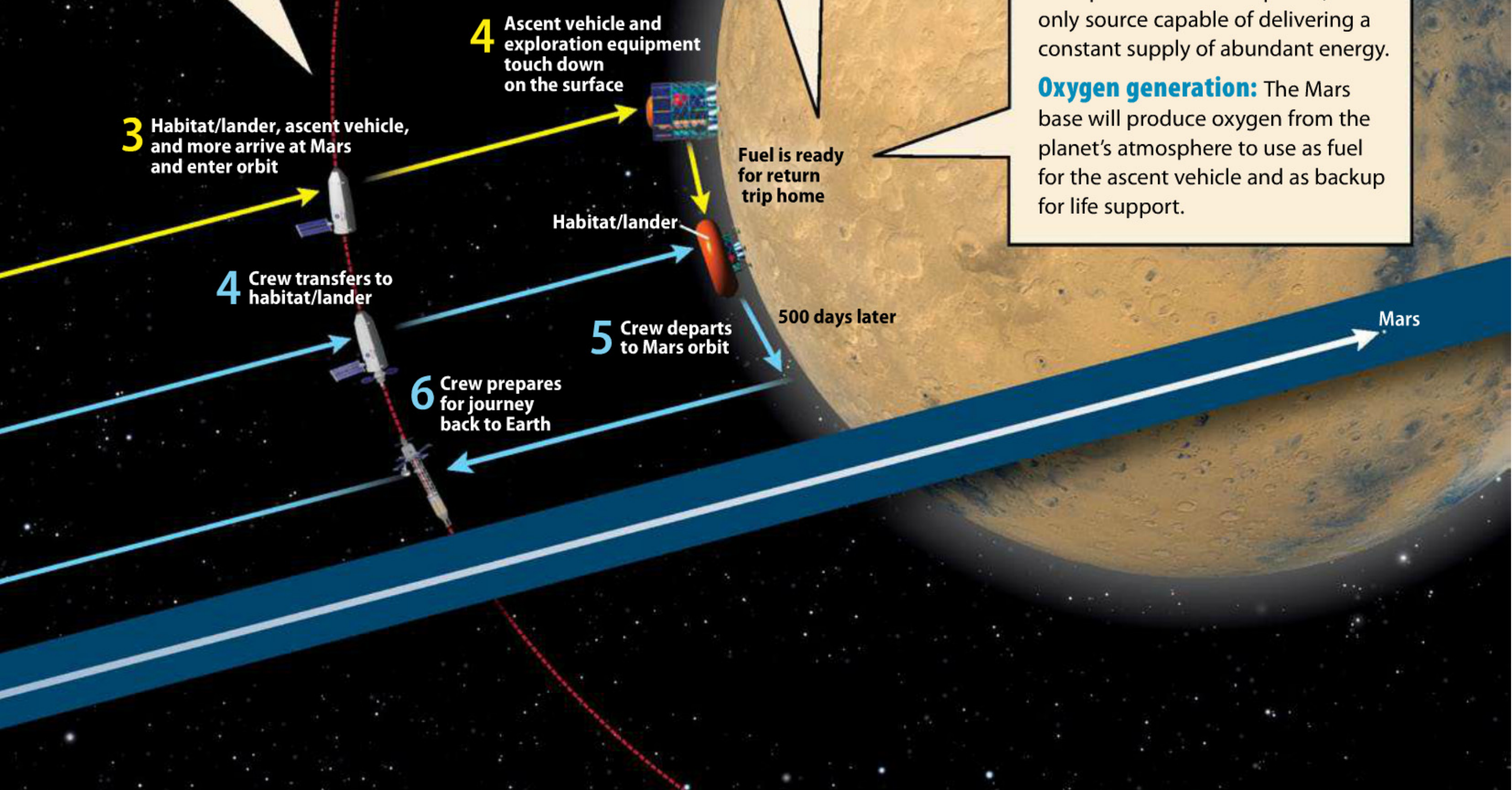
The so-called entry, descent, and landing phase of the mission carries high risk. Mission planners will have to devise a way to bring a 40- to 60-ton spacecraft from hypersonic orbital speed to a soft landing on the surface in less than 10 minutes.

Surface operations

When astronauts arrive, their equipment for exploring Mars will be waiting for them along with a fully fueled vehicle to return them to orbit. Rovers will carry the crew hundreds of miles from their safe landing site to study scientifically exciting regions.

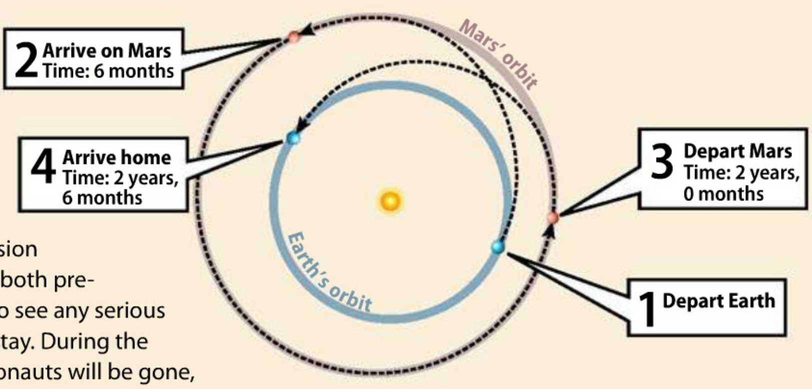
Power source: The Mars habitat will operate on nuclear power, the only source capable of delivering a constant supply of abundant energy.

Oxygen generation: The Mars base will produce oxygen from the planet's atmosphere to use as fuel for the ascent vehicle and as backup for life support.



Getting to Mars

The orbits of Earth and Mars present two reasonable options for a journey to the Red Planet. The first would keep astronauts on the surface for only about 30 days while the second would extend that to some 500 days. Mission designers and planetary scientists both prefer the latter option, and it's hard to see any serious expedition opting for the shorter stay. During the approximately 30 months the astronauts will be gone, Earth will complete 2.5 orbits and Mars 1.3 orbits.



Earth: NOAA/NASA GOES Project; Mars: NASA/JPL/USGS

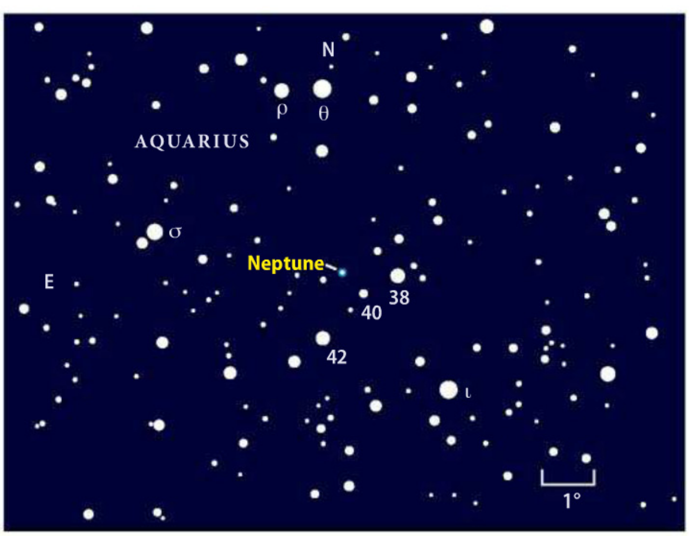
The Sky this Month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

August 2012

Neptune shines at its brightest

Neptune's atmosphere glows blue-gray through amateur telescopes, but don't expect to see details like Voyager 2 recorded in 1989. NASA/JPL



Neptune glows at magnitude 7.8 throughout August. It lies opposite the Sun on the 24th, when it appears 1° east of 38 Aquarii. *Astronomy*: Roen Kelly

Bright planets occupy both evening and morning skies this month while one of their fainter siblings, distant Neptune, reaches opposition and peak visibility. As darkness falls, Mars, Saturn, and Virgo's prominent star Spica form an elegant, color-contrasting trio. A crescent Moon adds to their beauty when it passes by on the 21st.

A more brilliant spectacle adorns August mornings. Both Mercury and Venus lie farthest from the Sun and highest in the sky at midmonth. Jupiter completes the scene from its perch above the two inner planets.

Our planetary tour begins August 1 when three 1st-magnitude objects hang low in the southwest as the sky darkens. **Saturn** and **Mars** shine at magnitudes 0.8 and 1.1, respectively, and stand 8° apart. With each passing day, the two approach each other. Between August 7 and 20, they lie within a 5° circle that also includes magnitude 1.0 Spica. On the 7th, the three form a neat equilateral triangle 4° on a side.

Sunlight reflecting off Saturn's cloud tops has a golden glow while Mars' ruddy deserts cast an orange hue. They contrast with the hot sun Spica, a blue giant star that generates its own light from a surface seething at 22,000 kelvins — nearly four times hotter than the Sun.

If you could take a time-lapse movie of these objects during August, you would see Mars and Saturn sliding in front of Virgo's stars. Mars, the closer of the two planets to the Sun, moves faster than distant Saturn. (The background stars remain stationary relative to each other.)

Consequently, Mars soon passes between Saturn and Spica. On August 13 and 14, the three form a nearly straight line. A week later, on August 21, the trio makes a second equilateral triangle (now with 5°-long sides) punctuated by a gorgeous crescent Moon hanging 4° below Mars. In the deepening twilight, the objects create a perfect scene for wide-angle photography. For the best shots, include some photogenic foreground trees or buildings.

Visible to the naked eye
Visible with binoculars
Visible with a telescope

By August 31, Mars trails 10° behind Saturn and Spica. The trio sets within two hours of the Sun.

When viewed through a telescope, Mars doesn't offer much. Its tiny disk measures 5" across, leaving everything to the imagination as it shimmers in the eyepiece. But the surface should come into sharp focus the night of August 5/6, the date NASA's Curiosity rover is set to touch down on the Red Planet. For more information about the car-sized rover's mission, see "Will Curiosity find life on Mars?" on page 20.

Although Saturn lies six times farther from Earth than Mars, the ringed planet looks far better through a telescope. That's partly because its physical diameter is 18 times bigger than Mars', so its apparent diameter is three times larger (16"). But even more important, Saturn has a beautiful ring system that spans 37". The rings tilt 14° to our line of sight in mid-August, offering us a fine view of their northern face.

With Saturn now hanging low in the evening sky, most of its moons will be difficult to spot. But its biggest and brightest satellite remains on view all month. Titan glows at 9th magnitude and takes 16 days to orbit Saturn. The moon appears closest to the planet when it passes either north or south of the globe. Look for Titan north of Saturn August 16 and south of it August 8 and 24.

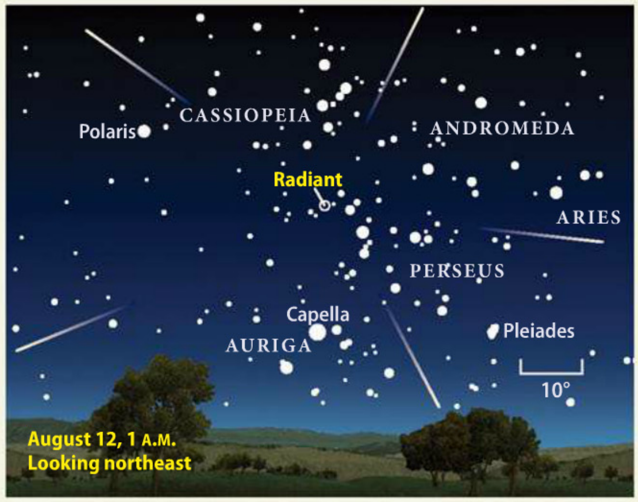
Neptune reaches opposition August 24, when it lies opposite the Sun in our sky and remains visible all night. It also appears brightest at opposition (magnitude 7.8), but it changes so slowly that you won't notice any difference during the month. And it's still dim enough that you'll need binoculars or a telescope to spot the distant world.

Neptune lies among the stars of Aquarius, in the same binocular field as 5th-magnitude 38 Aquarii. You'll find the planet 1.7° east of the star August 1 and

— Continued on page 42

Martin Ratcliffe *provides professional planetarium development for Sky-Skan, Inc., from his home in Wichita, Kansas. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

Meteor watch



The Perseid meteor shower peaks the night of August 11/12, when viewers can expect to see up to 80 meteors per hour. *Astronomy*: Roen Kelly

Perseids set to put on a great show

If weeknight observing leaves you tired and cranky, here's some good news: One of this month's premier events occurs Saturday night, August 11/12, when the Perseid meteor shower reaches its annual peak. Start observing around midnight local daylight time. Although a waning crescent Moon rises shortly after 1 A.M., it won't have much impact because the shower consistently produces lots of bright, fast-moving meteors.

Observers under clear dark skies likely will see 60 to 80 meteors per hour streaking across a spectacular predawn sky that includes the bright planets Venus and Jupiter. Perseid meteors are tiny chunks of rock and dust from Comet 109P/Swift-Tuttle. When Earth plows through this debris stream each August, our planet's atmosphere incinerates these particles.

Rising **Moon**

Youthful rays in a sea of ancient lava

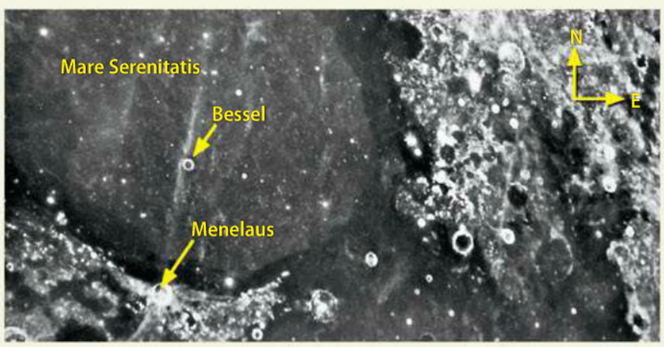
You can double your chances to catch some lunar rays this month. Two Full Moons grace August's sky, on the 1st and 31st. Although the second Full Moon in a calendar month has the popular nickname "Blue Moon," the completely lit orb on the 31st will be anything but blue. Full Moons in summer lie low in the southern sky for observers at midnorthern latitudes, so they tend to appear more yellow than their wintertime white. Throw in some haze from high humidity or smoke from forest fires, and the Moon may look orange or even pink.

Many lunar observers consider the Full Moon's most impressive feature to be the crater Tycho and its magnificent ray system. The rays are finely crushed particles that splashed out during the impact that formed Tycho. Your eye naturally follows the longest ray to the northeast, where it splits Mare Serenitatis (the Sea of Serenity) nearly in half.

The ray intersects Serenity's southern shore at the bright circular crater Menelaus. This 17-mile-wide impact structure has sharp edges and a light-hued debris apron that is characteristic of relative youth. Next, follow Tycho's ray northward into Mare Serenitatis, where it crosses the 10-mile-wide impact crater Bessel.

Now look carefully at the sea of ancient lava around these craters. Planetary scientists estimate that the darker shade is 3.8 billion years old. The lighter layer just to the north clocks in closer to 3 billion years. Can you see more white flecks — the telltale signs of tiny impact craters — in the darker, older zone?

Astronomers have learned that darkness usually equates with age on the Moon. Rays and debris aprons darken with time as energetic particles in the solar wind constantly blast the lunar surface.



Menelaus and Bessel stand out near the southern shore of Mare Serenitatis, particularly around Full Moon, when a bright ray from distant Tycho pierces the pair. *Consolidated Lunar Atlas*/UA/LPL

StarDome

The all-sky map shows how the sky looks at:
11 P.M. August 1
10 P.M. August 15
9 P.M. August 31

Planets are shown at midmonth

Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly

Quick fact: The Full Moon on August 31 is the second of the month, making it a "Blue Moon." This is the first Blue Moon for the Americas since December 2009; it won't happen again until July 2015.

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Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

Calendar of events

1 Full Moon occurs at 11:27 P.M. EDT

3 Jupiter passes 5° north of Aldebaran, 1 A.M. EDT

The Moon passes 6° north of Neptune, 6 P.M. EDT

6 The Moon passes 5° north of Uranus, 1 P.M. EDT

7 Mercury is stationary, 1 P.M. EDT

9 Last Quarter Moon occurs at 2:55 P.M. EDT

Asteroid Pallas is stationary, 4 P.M. EDT

10 The Moon is at apogee (251,110 miles from Earth), 6:51 A.M. EDT

11 The Moon passes 0.1° south of Jupiter, 5 P.M. EDT

Special observing date

12 The Perseid meteor shower peaks before dawn, when observers with clear skies can expect to see an average of 60 to 80 meteors per hour.

12 Mars passes 1.9° north of Spica, 8 P.M. EDT

13 The Moon passes 0.6° north of Venus, 4 P.M. EDT

15 Venus is at greatest western elongation (46°), 5 A.M. EDT

16 The Moon passes 4° south of Mercury, 1 A.M. EDT

Mercury is at greatest western elongation (19°), 8 A.M. EDT

17 Mars passes 3° south of Saturn, 5 A.M. EDT

New Moon occurs at 11:54 A.M. EDT

21 Asteroid Hygiea is at opposition, 4 P.M. EDT

The Moon passes 1.0° south of Spica, 6 P.M. EDT

The Moon passes 5° south of Saturn, 11 P.M. EDT

22 The Moon passes 2° south of Mars, 4 A.M. EDT

23 The Moon is at perigee (229,739 miles from Earth), 3:28 P.M. EDT

24 Neptune is at opposition, 9 A.M. EDT

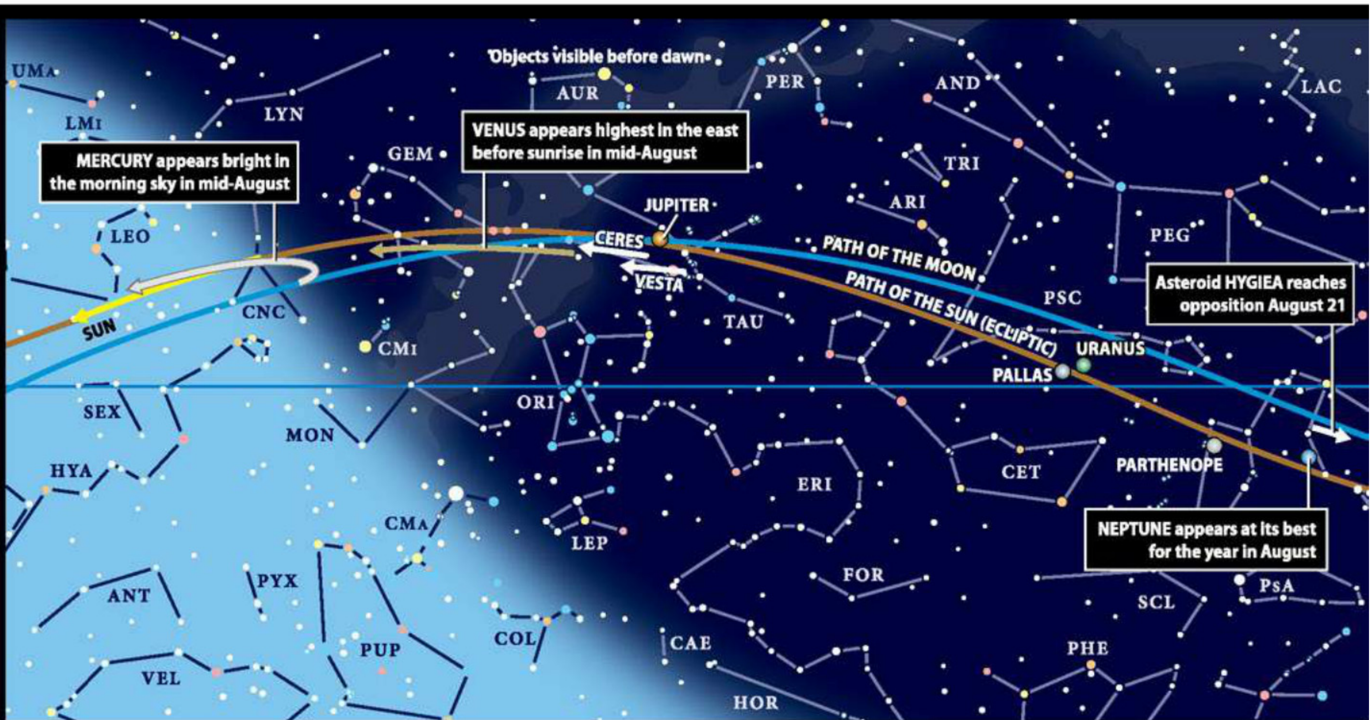
First Quarter Moon occurs at 9:54 A.M. EDT

26 The Moon passes 0.7° south of Pluto, 10 P.M. EDT

31 The Moon passes 6° north of Neptune, 1 A.M. EDT

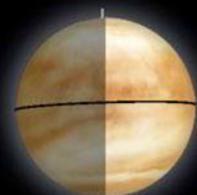
Full Moon occurs at 9:58 A.M. EDT

Planets in August 2012



MOON PHASES

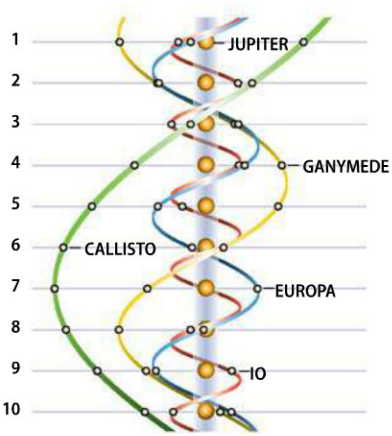
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

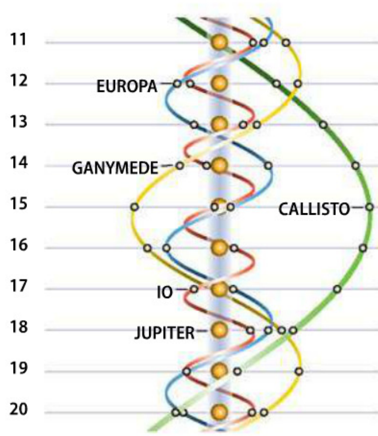



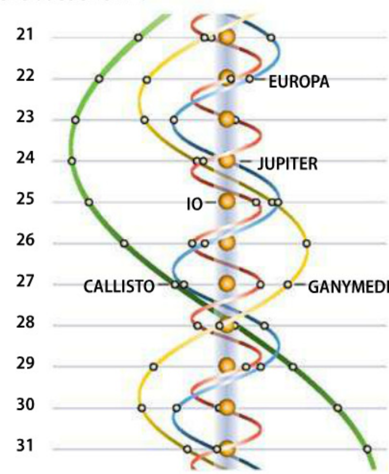
PLANETS	MERCURY	VENUS	MARS	CERES
Date	August 15	August 15	August 15	August 15
Magnitude	0.2	–4.4	1.1	9.0
Angular size	7.8"	23.7"	5.5"	0.4"
Illumination	36%	50%	91%	97%
Distance (AU) from Earth	0.864	0.705	1.711	3.057
Distance (AU) from Sun	0.337	0.726	1.525	2.766
Right ascension (2000.0)	8h23.4m	6h28.4m	13h29.8m	5h11.4m
Declination (2000.0)	17°54'	19°59'	–9°44'	19°29'

Jupiter's moons

Dots display positions of Galilean satellites at 4 A.M. EDT on the date shown. South is at the top to match the view through a telescope.







This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

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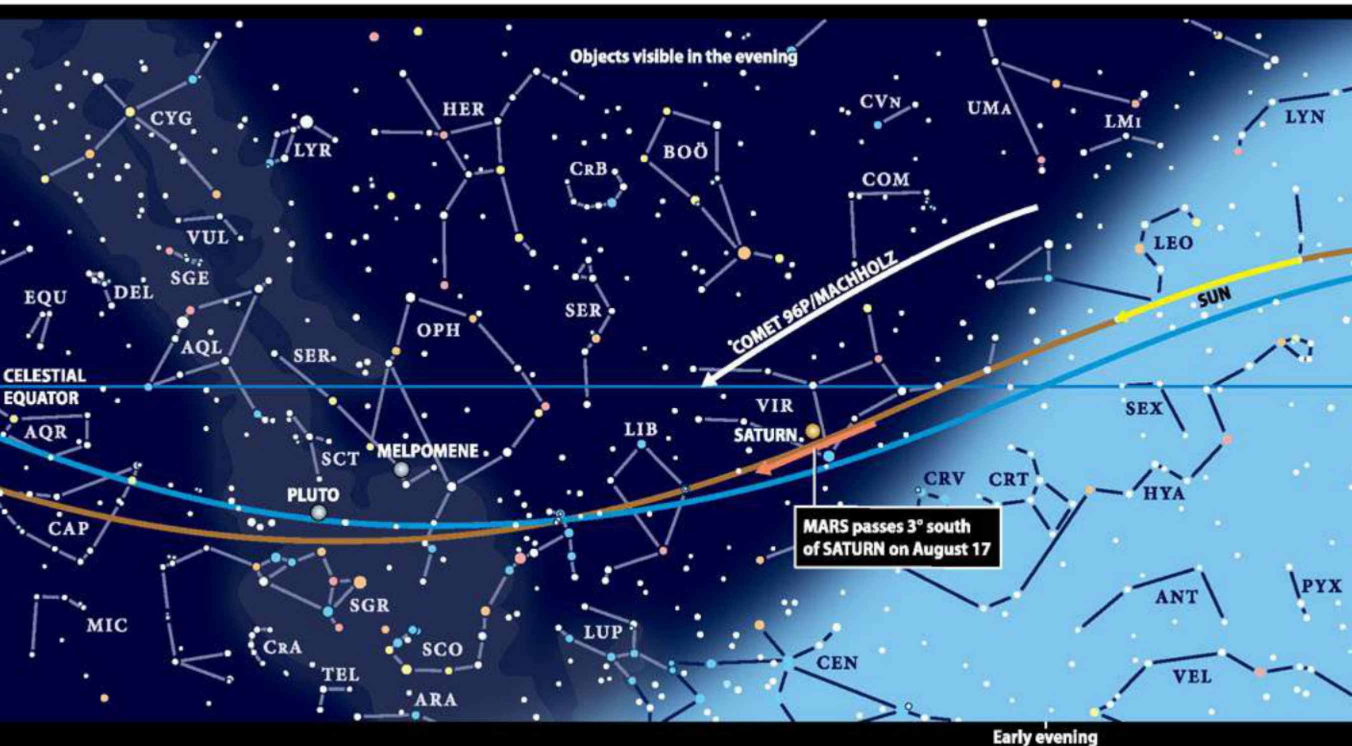
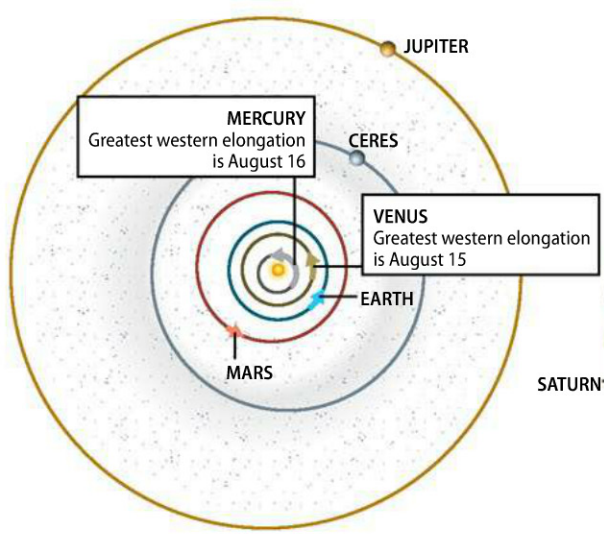
Path of the planets

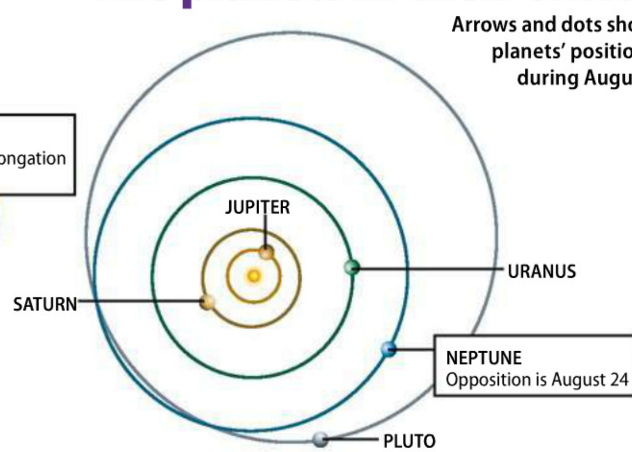


JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
August 15	August 15	August 15	August 15	August 15
–2.2	0.8	5.8	7.8	14.0
37.4"	16.3"	3.6"	2.4"	0.1"
99%	100%	100%	100%	100%
5.276	10.186	19.343	28.996	31.563
5.023	9.755	20.065	29.995	32.281
4h43.7m	13h34.7m	0h30.4m	22h16.2m	18h29.9m
21°29'	–7°20'	2°28'	–11°24'	–19°31'

The planets in their orbits

Arrows and dots show planets' positions during August.





— *Continued from page 37*

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Mars (southwest)	Uranus (east)	Mercury (east)
Saturn (southwest)	Neptune (southeast)	Venus (east)
Neptune (east)		Jupiter (east)
		Uranus (southwest)
		Neptune (southwest)

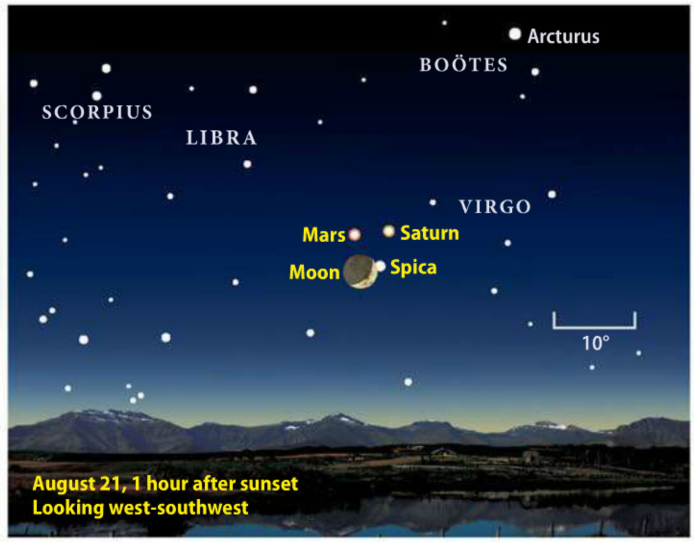
about half that distance by month's end. This region doesn't have many bright stars, so use the finder chart on page 36 to home in on the remote planet.

When you aim a telescope at Neptune, boost the magnification to see the planet's 2.4"-diameter disk. Note its distinct blue-gray hue, a color generated by the abundant methane in Neptune's atmosphere. This gas preferentially absorbs the red part of the solar spectrum and feebly reflects what's left.

Scan farther east in the late-summer sky to pick up **Uranus**. It lies in the northwestern corner of Cetus the Whale, just over the border from Pisces the Fish. These constellations rise in the east around the time Mars and Saturn set in the west. Like Neptune, Uranus lies in a region devoid of bright stars. To find the right area, scan with binoculars a bit more than one-third of the way from 3rd-magnitude Algenib, the star at the southeastern corner of the Great Square of Pegasus, to 2nd-magnitude Beta (β) Ceti.

Uranus and its stellar neighbor, 44 Piscium, both glow at magnitude 5.8. Through binoculars, the planet-star combination will look like a wide double star. On August 1, Uranus lies 1.6° east-northeast of 44 Psc. The gap closes to 51' (0.85°) by the 31st.

Larger binoculars (20x80, for example) or a telescope at low power will reveal a pleasing color contrast. The star shines at approximately the Sun's temperature, so it has a yellowish hue, while the planet glows blue-green courtesy of atmospheric methane. Increase the power on Uranus to see its 3.6"-diameter disk. Although this planet is about the same physical size as



Mars and Saturn dance with the star Spica during August, but be sure to pay attention when the Moon joins them on the 21st. *Astronomy*: Roen Kelly

Comet search

Spy a comet among Boötes' flock of stars

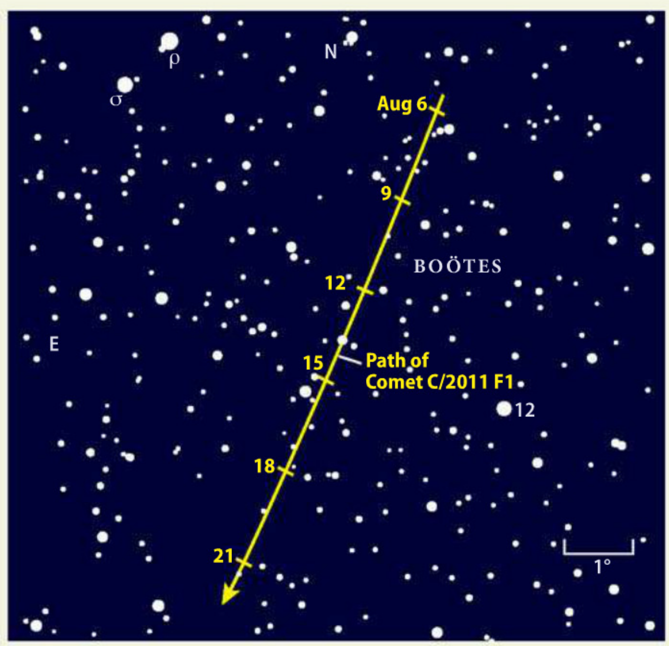
Whether you're breaking in a new telescope or reacquainting yourself with a dark sky at a summer star party, get ready to test your comet-hunting skills. This month's brightest visitor from the solar system's depths likely will be C/2011 F1 (LINEAR), which should glow feebly at 11th magnitude.

The comet floats above brilliant Arcturus in the western sky as night sets in. Wait until the Moon is out of the evening sky during the second and third weeks of August to hunt for LINEAR. Use the finder chart at right to zero in on the comet's position. Rho (ρ) and Sigma (σ) Boötis, the pair of 4th-magnitude stars at the map's top left, lie 12° north-northeast of Arcturus.

Using at least a 6-inch telescope, bump up the power past 100x to darken the background sky and make the comet's small diffuse patch a bit bigger. Gently tapping the scope's tube can help you pick up the ghostly glow because it brings your motion-sensitive averted vision into use. View the star chart with your non-observing eye to protect your dark adaption as much as possible.

If you're still having trouble, ask an observer with a larger light bucket for a quick look. Sometimes after you see a faint fuzzy in a big scope, you can detect it in a smaller one — another benefit of attending a star party.

Meanwhile, the morning sky offers a comet that might reach 10th magnitude. If we're lucky, Comet 185P/Petriew will experience an outburst similar to the one that allowed amateur astronomer Vance Petriew to discover it accidentally 11 years ago at the Saskatchewan Summer Star Party. This comet lies near the Crab Nebula (M1) in Taurus when it peaks in mid-August. Unless we get an unexpected visitor from the distant Oort Cloud, we won't see any comets brighter than 10th magnitude before late winter.



Comet C/2011 F1 (LINEAR) rides high in the western sky after darkness falls as it slides through the central part of Boötes. *Astronomy*: Roen Kelly

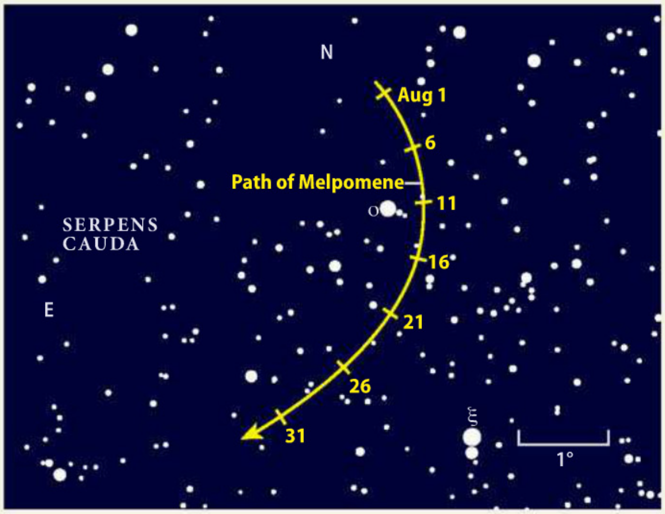
Locating **asteroids**

Melpomene loops through the Serpent's tail

The brightest asteroid on August evenings is 18 Melpomene. This 86-mile-wide space rock plies the southwestern section of Serpens Cauda, the tail of the Serpent, near that constellation's border with Ophiuchus the Serpent-bearer. This region climbs highest in the south as darkness falls. Wait until the bright Moon leaves the evening sky around August 4 to track the magnitude 10.0 Melpomene.

Start your search at 2nd-magnitude Eta (η) Ophiuchi in the lower left corner of the Serpent-bearer. Then, shift a finder scope's field of view to the east to your target. Melpomene remains within a couple of degrees of 4th-magnitude Omicron (ο) and Xi (ξ) Serpentis all month.

Note how the number of stars increases in the southern part of the field. With less obscuring gas and dust in this sector of the Milky Way, the distant lights shine through more easily. Of course, the higher star count also makes it harder to pinpoint the asteroid. Which point of light is it? You should be able to discern Melpomene from the pattern of stars on the finder chart. To be sure, plot the star field and label your suspect. Return to the same field a night or two later and confirm the asteroid by seeing which "star" moved.



A handful of bright guide stars in Serpens Cauda makes it fairly easy to track Melpomene this month. *Astronomy*: Roen Kelly

Neptune, it appears 50 percent bigger because it lies two-thirds as far away.

The cavalcade of morning luminaries begins when **Jupiter** pokes above the horizon. This striking object rises shortly before 2 A.M. local daylight time August 1. Shining at magnitude –2.2, Jupiter lies 5° due north of 1st-magnitude Aldebaran, the red giant star that marks Taurus the Bull's eye. A waning crescent Moon joins the pair August 11. The planet slowly crosses Taurus during August, ending the month in the middle of the Bull and rising shortly before midnight local daylight time.

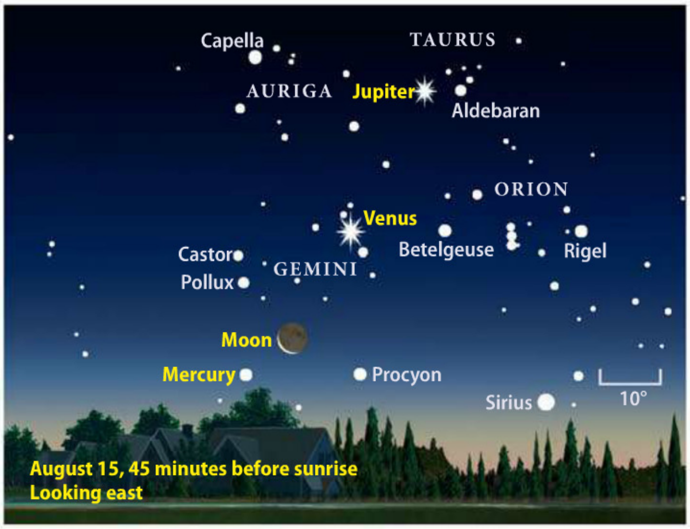
Any telescope reveals Jupiter's disk, which grows from 36" to 39" across during August. Even small instruments show plenty of atmospheric detail. Look for a series of bright zones alternating with darker belts that run parallel to the giant planet's equator. Up to four bright moons join every scene. If you see fewer than four of these Galilean satellites, it means one or more of them is hiding in front of or behind the massive planet.

The next planet on display is the only one brighter than Jupiter. **Venus** reaches greatest elongation August 15, when it lies 46° west of the Sun and rises more than three hours before our star. The brilliant planet dominates the morning sky, at least when the Moon isn't nearby. Venus gleams at magnitude –4.6 at the beginning of August and fades only to magnitude –4.3 by month's end.

On the 1st, Venus stands 2° south of 3rd-magnitude Zeta (ζ) Tauri, the southern horn of the Bull. Between August 5 and 12, the planet crosses Orion the Hunter's raised arm. A crescent Moon joins Venus on August 13, by which time the planet is tickling the feet of Gemini the Twins. Venus closes the month 9° south of 1st-magnitude Pollux, the Twins' brightest star.

The period surrounding greatest elongation is always an exciting one for planetary observers. When viewed through a telescope this month, Venus shrinks and its phase waxes dramatically. Over August's 31 days, its apparent diameter drops from 28" to 20" while its illuminated fraction grows from 42 to 58 percent.

Mercury comes to greatest western elongation a day after



A parade of planets lights up the dawn sky all month. Mercury and Venus reach greatest elongation on consecutive days in mid-August. *Astronomy*: Roen Kelly

Venus. But at an angular distance of only 19° from the Sun, the innermost planet hugs the eastern horizon. Start looking for it around August 11. It then shines at magnitude 1.0 and rises about 80 minutes before sunrise. It quickly brightens, however, reaching magnitude –0.1 by greatest elongation August 16. That morning, it stands 10° above the horizon 30 minutes before the Sun rises.

Mercury grows brighter as the month progresses, partially offsetting its lower altitude. You should be able to track it until August's final week, when it reaches magnitude –1.0 but lies only half as high in the predawn sky.

Mercury's telescopic appearance changes at a much faster pace than Venus'. When it first comes into view August 8, the innermost planet spans 9" and shows a 15-percent-lit phase. At greatest elongation, it displays a 7"-diameter disk that is 42 percent illuminated. And a week after that, Mercury appears 6" across and 69 percent lit.

Mars mania

The Red Planet's

Since antiquity, Mars has captured our minds and imaginations, and its study has led to important discoveries — and some of the greatest misconceptions — in planetary science. **by Karri Ferron**

When the ancient Greeks looked up at the night sky, they were fascinated by "wandering stars" that traced paths across the heavens. One in particular stood out: a red *planētē* that briefly moved backward in a looping motion every two years before correcting its path. True, two other "stars" also reversed direction, but this one's movement was faster and therefore more pronounced. The Greeks named the bloody wanderer after their god of war, Ares — Mars to the Romans.

Since then, the Red Planet has influenced more astronomers, generated more debate, and been the subject of more stories than any other planet. But why has Mars created such interesting finds and fanciful facts? The answer lies in the Red Planet's colorful relationship with Earth.

Of gods and motions

As many as 5,000 years ago, the Egyptians understood Mars' unique path through the sky and called it *sekhed-et-em-khet-ket* (one who travels backward). Most other cultures gave the reddish wanderer a more sinister name because such a motion signified disorder and distrust. To the Babylonians, Mars was *Nirgal* (star of death), while it was *Angakara* (burning coal) in India.

Of course, the two most common names associated with the planet were Ares and Mars, the gods who each had significant influence on the ancients. The Cult of Ares existed from the 11th century B.C. to the fourth century A.D. For the Roman Empire, Mars was its protector and the father of Romulus and Remus, the founders of Rome.

But Mars' influence wasn't only mythological. Its unusual retrograde path puzzled scholars. In the fourth century B.C., Eudoxus of Cnidus, a student of the Greek philosopher Plato, began studying this motion. He supposed that Mars moved as if it were a small rotating sphere pinned to the rim of a larger wheel; he was also the first to suggest the planet had a tilted axis of rotation.

The Greek astronomer Ptolemy conducted numerous observations of Mars in the second century A.D. while trying to understand Aristotle's complicated model of 55 solar system spheres. In the end, he made this "epicycle theory" even more complex. Still, he was able to calculate roughly the Red Planet's motion across the sky.

Ptolemy's *Almagest* remained the authoritative text on astronomy throughout the Middle Ages. It wasn't until Tycho Brahe (1546–1601) that Mars' motion again began to cause a stir. Tycho studied the Red Planet closely at every opposition (when the planet lies opposite the Sun in

Mars' retrograde motion around opposition intrigued observers even in ancient times. It also made understanding Mars difficult for many astronomers.

Tunç Tezel

colorful past

Photo collage by *Astronomy*: Alison Mackey

Earth's sky) after 1580. A year before he died, Tycho met Johannes Kepler (1571–1630) and assigned the German mathematician the task of understanding Mars' movement through the sky.

After 10 years of work, Kepler developed his laws of planetary motion, which matched Tycho's observations of the Red Planet. Using a Sun-centered system with elliptical orbits, he could predict Mars' movement.

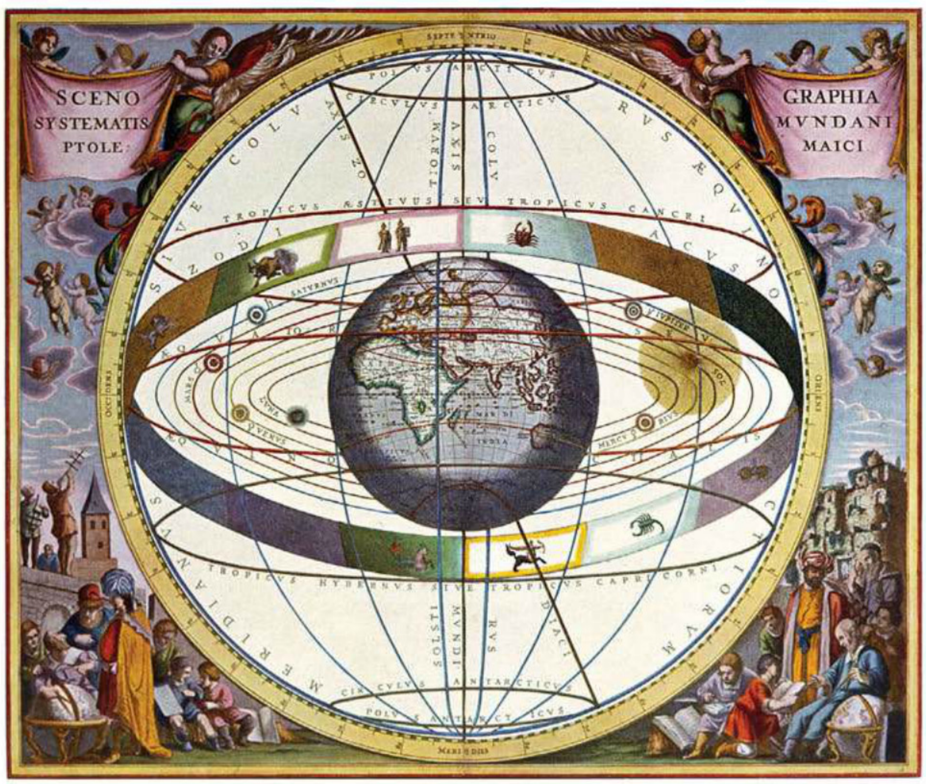
A telescopic revolution

Kepler released his results in 1609, the same year the Italian astronomer Galileo Galilei (1564–1642) pointed his rudimentary telescope skyward and began a renaissance in astronomy. It wasn't until the middle of the century, though, that a picture of the Red Planet became clearer.

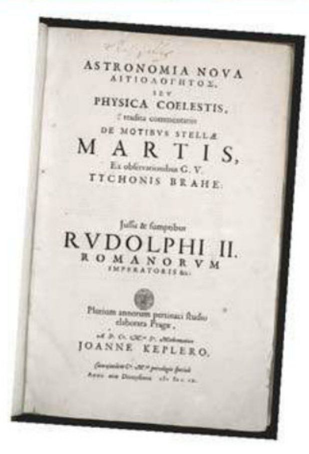
Much of that credit goes to Dutch astronomer Christiaan Huygens (1629–1695). In 1659, he noticed a triangle-shaped dark area across Mars' face. His sketch of what is today called Syrtis Major was the first such drawing of a martian surface feature.

Using the shape as a guide, Huygens began an extensive record of how the Red Planet rotates, coming up with a rate of 24 hours, the same as Earth. He also made a fairly accurate guess of Mars' size and wrote philosophically about the civilizations he believed lived on Mars and the other planets.

Meanwhile, Italian-French astronomer Giovanni Domenico Cassini (1625–1712) also was observing martian surface features. He refined the Red Planet's rotation period



▲ **Ptolemy's epicycle theory** of the second century B.C. attempted to explain the motions of the planets. To describe that of Mars, the astronomer had the planet move uniformly about a point that then moved around Earth. Mary Evans Picture Library



▶ **Johannes Kepler's laws of planetary motion,** published in 1609, were based on 10 years of studying Mars, a task assigned to him by fellow astronomer Tycho Brahe. To explain the path of the Red Planet and others, Kepler developed a Sun-centered system with elliptical orbits. Linda Hall Library of Science, Engineering & Technology

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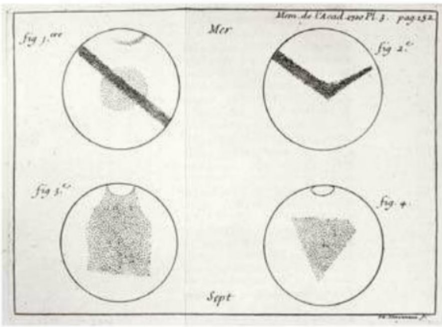
Karri Ferron *is an* Astronomy *assistant editor. Writing about Mars' colorful past combined two of her favorite subjects: planetary science and astronomical history.*



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What is now known as Syrtis Major was one of the first identified surface features on Mars, sketched by Christiaan Huygens in 1659. Giacomo Filippo Maraldi continued Huygens' work, as shown in these four drawings. Syrtis Major is at the bottom right.

to 24 hours and 40 minutes (today's known value is 24 hours, 37 minutes, 22 seconds). And during Mars' close approach to Earth in 1672, he and his colleague Jean Richer used observations of the Red Planet to refine the distance between our planet and the Sun to within 6 million miles (10 million kilometers) of the correct measurement.

Cassini's nephew Giacomo Filippo Maraldi (1665–1729) took up Mars next, studying the planet extensively until 1719. In 1704, he first observed white spots on both of the Red Planet's poles. By the 1719 opposition, he suggested that the areas could be ice caps because the southern one grew and shrunk with the martian seasons.

German-born English astronomer William Herschel (1738–1822) confirmed Maraldi's finding during the 1777 opposition and noted that the spots could be composed of water-ice. A few years later, while observing a close passage of Mars in front of two faint stars, Herschel concluded that the Red Planet must have a thin atmosphere because it had little effect on the background stars' light. He also discovered that Mars had an axial tilt of 30° (the correct value is closer to 25.2°), only slightly greater than Earth's 23.4°, meaning the Red Planet had comparable seasons, only longer.

Because Herschel, like Huygens, believed in inhabitants on other planets, he thought that those on Mars "probably enjoy a situation in many respects similar to ours." Martians didn't become menacing until later.

Mapping Mars

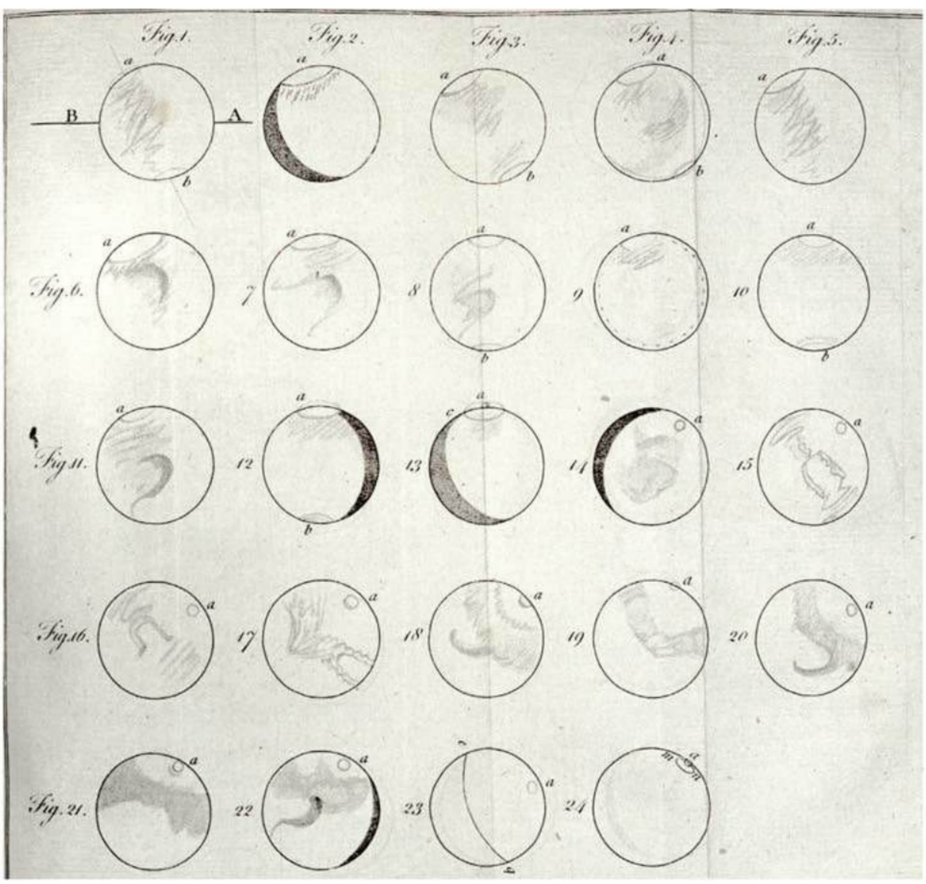
An image of Mars interspersed with blue-green patches, possibly oceans or vegetation, came to the forefront as 19th-century astronomers began to map the martian surface. The first to do so were Wilhelm Beer (1797–1850) and Johann Heinrich von Mädler (1794–1874) in 1830. They used a small round patch just south of the true equator as their zero meridian, a marker martian cartographers still use today.

The next significant drawings came from the Jesuit astronomer Pietro Angelo Secchi (1818–1878). He was the first to call Syrtis Major an ocean during the 1858 opposition, and in 1863, he made an attempt to draw the complex color scheme he observed on Mars. Based on the various reds, greens, and blues, he wrote, "The existence of seas and continents … has been conclusively proved."

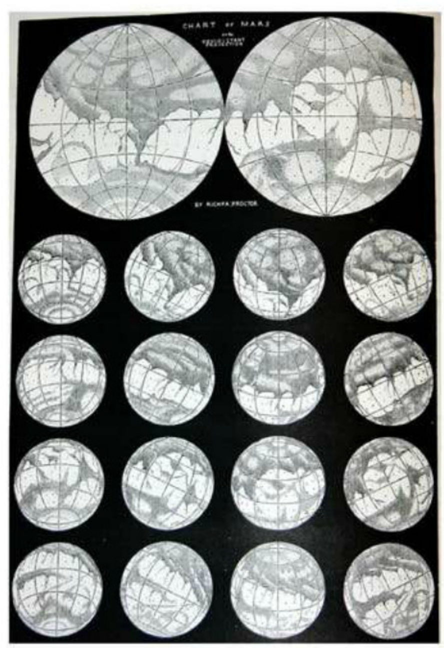
A year later, Reverend William Rutter Dawes (1799–1868) created 27 drawings of Mars, all so vivid that they inspired English astronomer Richard Anthony Proctor (1837 –1888) to use them for an 1867 map. The result would stand for two decades before one man's observations changed everyone's view of the Red Planet.

The mystic *canali*

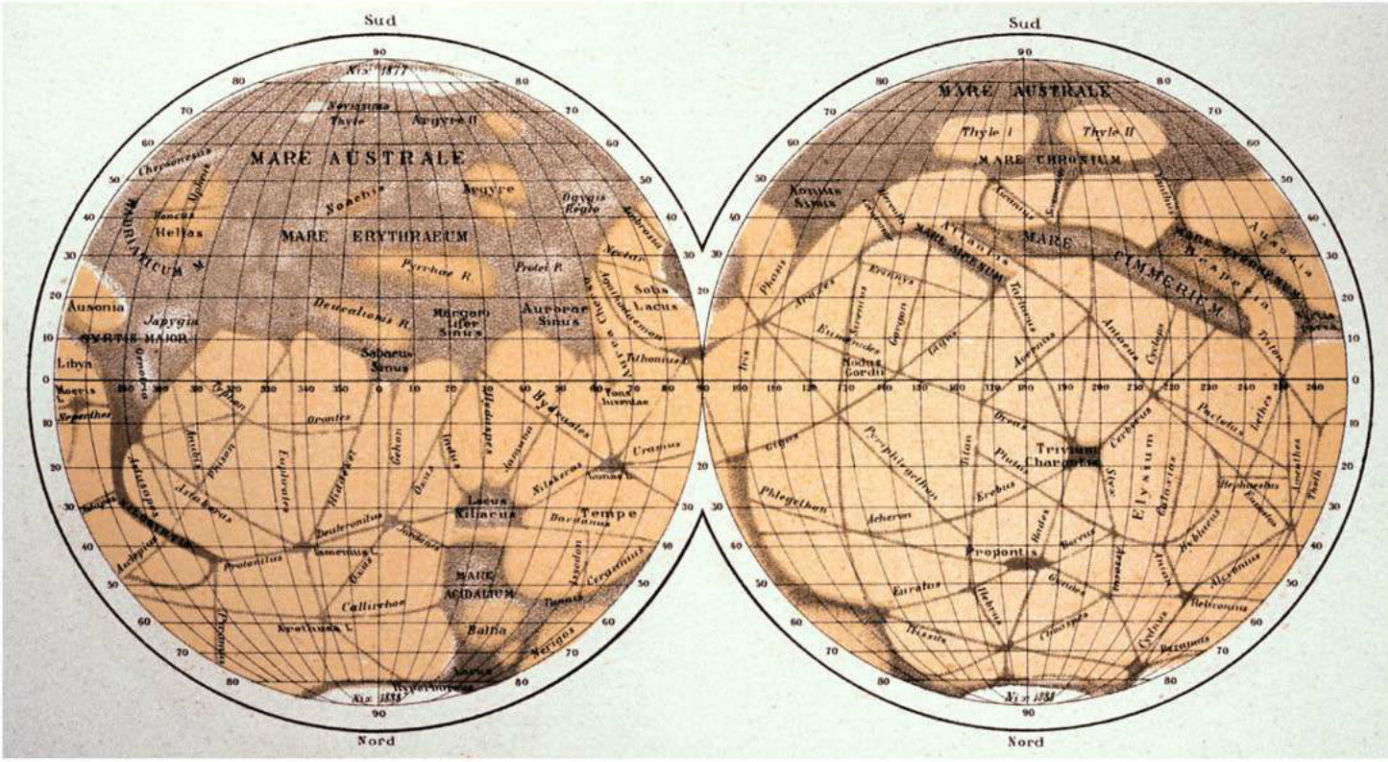
The year 1877 brought a Mars opposition that also came during the planet's closest point to Earth, making it the target of many astronomers. At the U.S. Naval Observatory, Asaph Hall (1829–1907) discovered



William Herschel recorded the Red Planet's changing seasons in 1784. He believed they were comparable to those on Earth, only longer. Linda Hall Library of Science, Engineering & Technology



Richard Anthony Proctor's map of Mars, published in 1867 and based on 27 drawings by Reverend William Rutter Dawes, stood as the pre-eminent chart of the Red Planet for more than two decades. Michael E. Bakich library



Giovanni Schiaparelli's late-19th-century map of Mars caused an uproar when he identified thin lines across the surface as *canali*. In Italian, this means grooves or channels, but the English translated the term as man-made canals. Linda Hall Library of Science, Engineering & Technology

two moons circling the Red Planet, which he eventually named Phobos and Deimos after the Roman gods of fear and panic, respectively. Meanwhile, Giovanni Virginio Schiaparelli (1835–1910) set out to map Mars' geography using an 8.6-inch refractor in Milan, Italy. He noted that the main continents Proctor had drawn were actually multitudes of islands. But most importantly, he plotted an intricate network of linear features, which he named *canali*.

In Italian, *canali* means channels or grooves; it is evident that this is what Schiaparelli meant based on his use of *fiume* (rivers) as a synonym. But to the English, these features became man-made canals.

Although Schiaparelli believed the channels were natural, the idea that only intelligent life could create such intricate waterways ran rampant. Science-fiction author Camille Flammarion's (1842–1925) 1892 best-seller, *La planète Mars et ses conditions d'habitabilité* ("The planet Mars and its habitability conditions"), bespoke the utopia of Mars and the influence of Schiaparelli's work. "It would be wrong to deny that [Mars] could be inhabited by human species whose intelligence and methods of action could be far superior to our own," he wrote. "Neither can we deny that they could have straightened the original rivers and built a system of canals with the idea of producing a planet-wide circulation system."

Finally, in 1893, Schiaparelli spoke out about the *canali* he discovered in *La vita sul pianeta Marte* ("Life on the planet Mars"): "It is not necessary to suppose them the work of intelligent beings, and … we are now inclined to believe them produced by the evolution of the planet."

But it was too late. On Christmas Eve 1893, Flammarion's *La planète Mars* landed in the hands of the man who would become the most staunch supporter of the canals and life on Mars: Percival Lowell.

Lowell's Mars

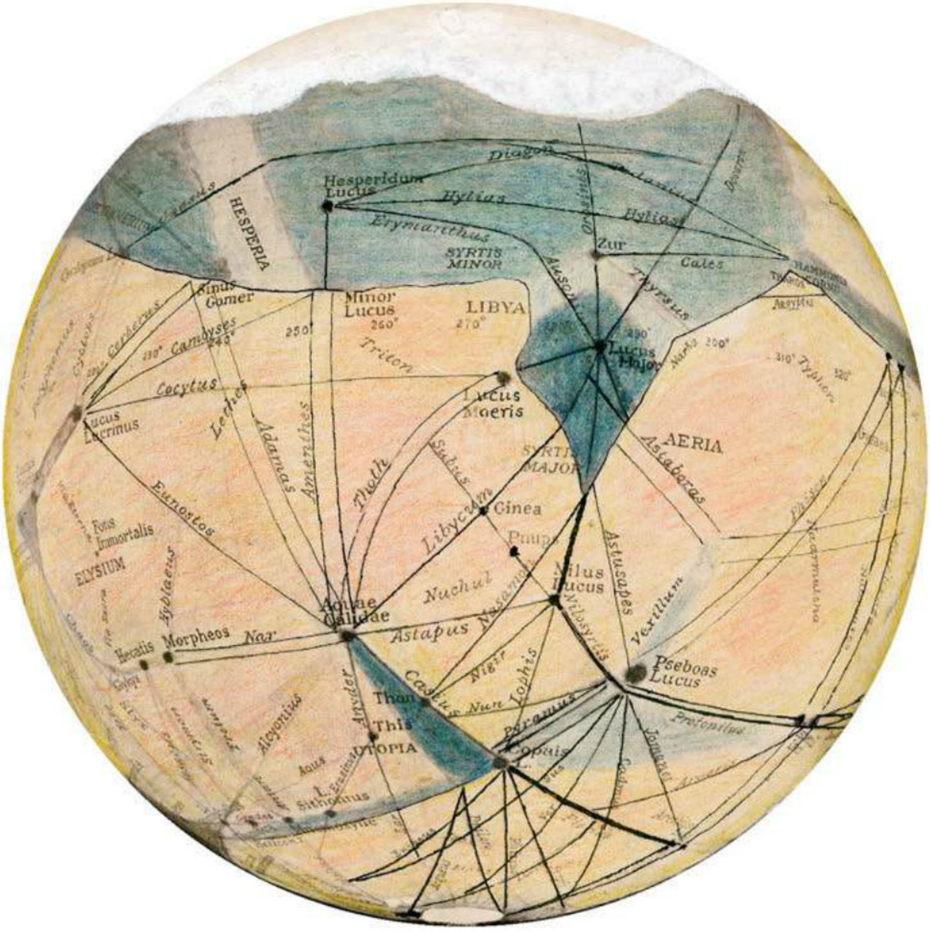
After reading Flammarion's book about the potential to find life on the Red Planet, wealthy American businessman Percival Lowell (1855– 1916) decided to make Mars his life's work. In 1894, he built a mountaintop observatory near Flagstaff, Arizona, for his research, believing he would soon provide a "pretty definite discovery" about life on Mars.

Lowell and his staff mapped more canals than any previous observers during the 1894 opposition. He suspected that Schiaparelli's "oceans" had no water, which observations confirmed. Instead, he concluded that these dark areas were vast tracts of vegetation.

In Italian, *canali* means channels or grooves. … But to the English, these features became man-made canals.

In one of the most influential books about the Red Planet (*Mars*, 1895), Lowell depicted the world as a desert similar to Arizona, with thin air and the occasional oasis. The straightness of the canals he saw meant they were artificial and created for martian survival after their planet had lost much of its water supply.

But Lowell had many critics. Although not a vocal one, Edward Emerson Barnard (1857–1923) made observations that conflicted with those made in Flagstaff. In 1894, using the 36-inch Lick Refractor atop Mount Hamilton in California, Barnard failed to see *any* canals. Still, he did see mountains and plateaus, and he even suggested that Syrtis Major might be the



Percival Lowell's Mars included more canals than any previous astronomer had observed. He also believed that the dark areas on the Red Planet were vast tracts of vegetation. Lowell Observatory Archive

Percival Lowell built an observatory in Flagstaff, Arizona, in 1894 for the sole purpose of searching for signs of life on Mars through a 24-inch refractor. Lowell Observatory Archive

latter instead of an area of vegetation (which is, in fact, true).

Lowell's most vocal opponent, though, was Eugène Michel Antoniadi (1870–1944). During the 1909 opposition, the Greek-born French astronomer observed Mars through the 33-inch refractor at Meudon Observatory in Paris — the largest refractor in Europe. Instead of canals, he saw disconnected patches of ridges and craters. The features Lowell and others claimed to see, he said, were only visible through a turbulent atmosphere that distorted the view. As Antoniadi wrote in a letter to colleagues, "The spider's webs of Mars are doomed to become a myth of the past."

Mars attacks

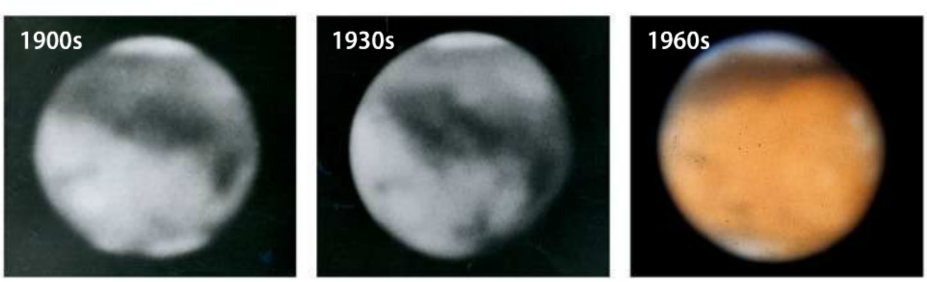
Despite this mounting opposition, Lowell's canals lived on into the 1960s, and the idea of life on Mars highly influenced popular culture. But unlike Lowell's martians, who were benevolent, the Mars of science fiction was full of war-loving inhabitants.

The first to depict martians as monsters was H. G. Wells in *War of the Worlds*, published in 1897. The interplanetary war story details ruthless martians who invade Earth. Broadcast as a radio play more than four decades later, it would become the defining moment of Mars in science fiction.

The most popular martian monsters of Lowell's time were the result of Edgar Rice Burroughs' (1875–1950) "Barsoom" series about the earthly hero John Carter. Barsoom was the author's fictional representation of Mars and was largely based on Lowell's observations — a civilization dying in the deserts — but Burroughs added six-legged green martians.

In the 1920s, pulp magazines ushered in the golden age of science fiction. Although many young authors in these easily produced tabloids were influenced by Lowell's Mars, they cared little for scientific fact. Meanwhile, with the invention of radio communication, claims of signals from Mars often occurred, fueling the lingering belief in life on the Red Planet.

Then, in what has become one of the most famous radio broadcasts in history, Orson Welles (1915–1985) adapted *War of the Worlds* for his *The Mercury Theatre on the Air* series October 30, 1938. More than 1.7 million people listened in as "news bulletins" told of martians invading Earth. Despite advance warnings that this was a fictional broadcast, the program brought panic, as many listeners tuned in late. Because inhabitants on Mars were still

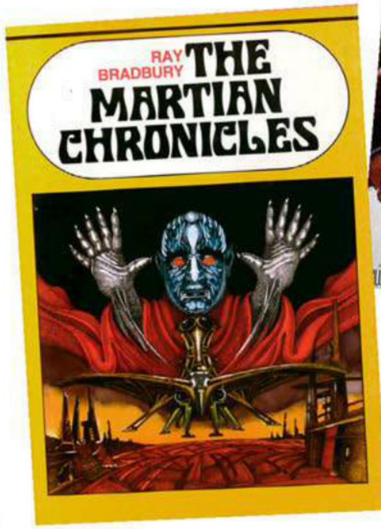


While telescopic photographs of Mars improved between the 1900s and 1960s, the best ones were still blurry, so the existence of the canals remained inconclusive. Lowell Observatory Archive (1900s and 1930s); LPL (1960s)

Mary Evans Picture Library

H. G. Wells' *War of the Worlds,* published in 1897, first introduced martians as monsters. This illustration from a 1906 reprint of the story shows the first alien emerging from its ship.

▶ *Invaders from Mars* capitalized on America's strong anti-communist sentiment in the 1950s by hiding evil martians in the minds of humans — analogous to the invisible threat of communism. Mary Evans Picture Library



◀ Ray Bradbury's *The Martian Chronicles* is considered one of the best science-fiction novels of all time. This 1951 collection of 27 short stories details the human fight to colonize Mars after fleeing a devastated Earth. Karri Ferron library

theoretically possible and people relied on the radio to get their news about the unrest in Europe and the Pacific, listeners took the broadcast to heart.

Cold War influence

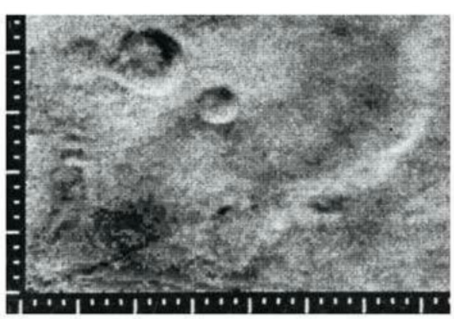
Mars and martians took a backseat during the height of World War II, but the fear caused by the ensuing conflict between the United States and the Soviet Union during the Cold War had a vast impact on humans' relationship with the Red Planet, both fictional and real. Parallels to the Red Scare (strong American anti-communism sentiment) and the threat of atomic weapons seeped into the story lines of science-fiction novels and movies in the 1950s.

In some films, like *Invaders from Mars* (1953), evil martians echoed America's paranoia over an unknown enemy — these aliens could mask themselves as humans through mind control, making them just as unrecognizable as communists. In others, such as *The Day the Earth Stood Still* (1951), they were a benevolent society attempting to save Earth from the nuclear arms race.

Meanwhile, the most famous Red Planet novel of the time was *The Martian Chronicles*, written as a collection of 27 short stories for magazines by the celebrated science-fiction author Ray Bradbury and published into a book in 1951. He returned to the Mars of Lowell, with the planet's ecology somewhat conducive to life but faced with a near-extinct race. His earthly characters fight to colonize Mars after fleeing from an Earth devastated by atomic warfare.

The Cold War also had great influence on real-life studies of the Red Planet. A major part of this conflict involved technological competitions, including the space race. Artificial satellites launched in the late 1950s indicated that unmanned exploration of other planets was possible.

The Soviets were the first to endeavor to explore Mars in 1960, but the spacecraft failed to reach Earth orbit. Multiple subsequent attempts resulted in similar outcomes. Then, in November 1964, the United States launched two Mariner spacecraft to perform flybys of Mars. Although Mariner 3 was lost, its sister craft reached its destination. And what it saw would completely change scientists' view of the Red Planet.



The martian canals disappeared in July 1965 with the arrival of NASA's Mariner 4, which sent back 22 postage stamp-sized images of a cratered world with no signs of life. NASA/JPL

The truth revealed

On July 15, 1965, Mariner 4 flew 6,118 miles (9,846km) above the surface of Mars, capturing 22 postage stamp-sized photos to send back to Earth. The images showed no canals and no signs of life — only craters and plateaus. What Lowell had insisted he saw from Earth were in fact chains of crater walls — dots that, from a distance, blurred together to form lines.

The impact craters made the martian surface look more like that of the Moon than of a world that was once possibly inhabited. Measurements of the Red Planet's thin atmosphere were also surprising. Mariner 4's radio signal indicated a surface pressure of between 4.0 and 5.1 millibars (thousandths of a bar, where 1 bar is about the surface pressure of Earth's atmosphere). Before the spacecraft's arrival, most estimates hovered between 85 and 87 millibars, with only one going as low as 25. Mars wasn't Earth-like at all.

Today, we know Mars is much different from what scientists believed they had found in 1965 — another Moon. Still, those images put to rest a colorful and often fanciful picture of the Red Planet not based in reality. Astronomers now are using fresh discoveries to paint a new portrait of Mars — one just as exciting as the Red Planet of the past 5,000 years.

Explore more of Mars' colorful history at www.Astronomy.com/toc.

Astronomy's experts from around the globe answer your cosmic questions.

Rocks from space

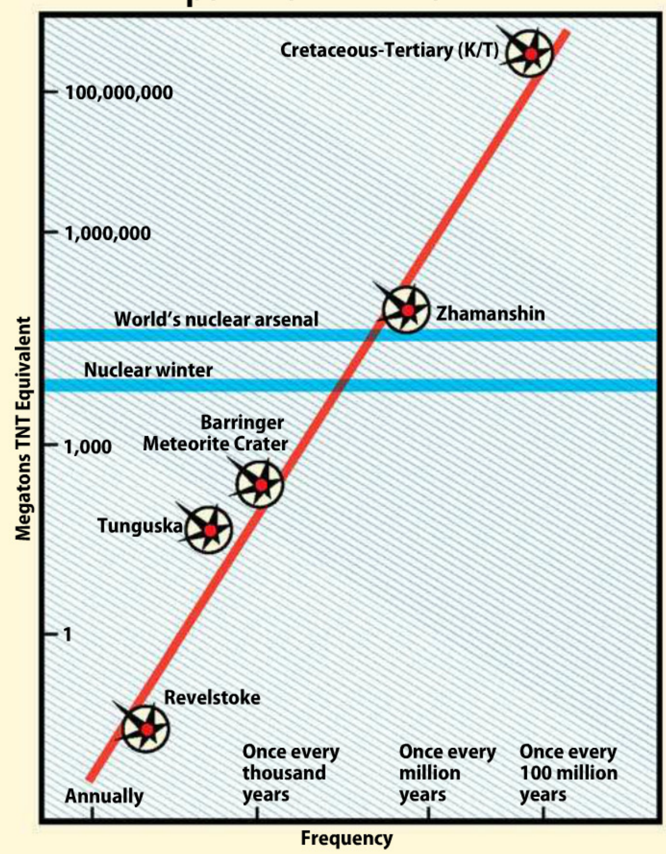
Q: When a really big rock (or a huge chunk of iron) hits Earth, why does it explode instead of just making a lot of rubble? — **Bill Albertson,** Ann Arbor, Michigan

A: In 1924, Algernon Charles Gifford wrote in the somewhat obscure *New Zealand Journal of Science and Technology* that **meteorite impacts are profoundly different from the more familiar impacts of bullets because of the enormous energy objects moving at meteoritic velocities carry.** He computed that a meteorite traveling at 7,200 mph (11,600 km/h) (and that's relatively slow — the average impact velocity on Earth is actually about 36,000 mph [58,000 km/h]) contains as much energy as an equal mass of TNT. (This is because energy is proportional to the velocity squared.) Gifford proposed that, **at such speeds, the final crater is essentially blasted out as if by an explosion, rather than by simply pushing material aside.**

The energy content of impacting meteorites is larger than the energy required to melt or even vaporize the projectile completely. While about half of this energy goes toward opening the crater, the remaining energy stays in the impactor and ultimately disperses it into tiny droplets of molten iron — as occurred at Barringer Meteorite Crater in Arizona — or even as rock vapor.

In 1900, Daniel Moreau Barringer first investigated the site eventually named in his honor as a potential source for the nickel-iron he believed was buried beneath the crater floor. Despite vigorous attempts to locate the supposed mass of iron, none was ever found. Finally, in 1946, meteoriticist Henry H. Nininger recognized that small pieces of iron scattered outside the crater were all that remained of the projectile. — **Jay Melosh,** Purdue University, West Lafayette, Indiana

Space rocks versus TNT



A space rock hurtling toward Earth at speeds of several miles per hour contains as much energy as an equal mass of TNT, and thus explodes at our planet's surface. This diagram compares how frequently impacts of equivalent TNT energy occur. *Astronomy*: Roen Kelly, after Alan Harris

CREATING A STELLAR EXPLOSION

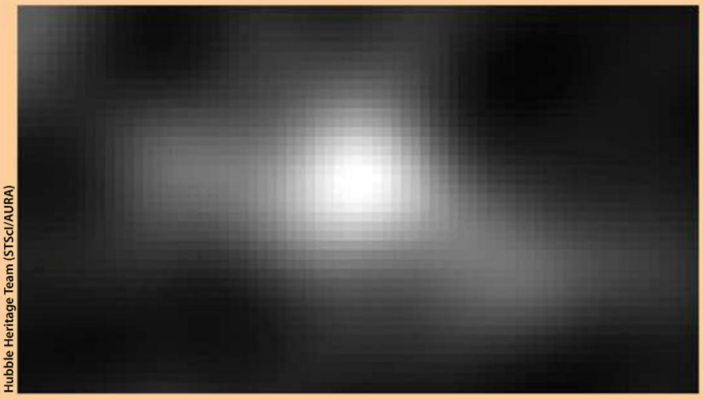
Q: I read recently about the possibility of two white dwarfs colliding to create a type Ia supernova. Why do astronomers think it has to be two white dwarfs instead of a white dwarf colliding with a regular star? — **Steven Smith,** Charlotte, North Carolina

A: We have known for a while now that a type Ia supernova comes from a white dwarf that has exceeded the "Chandrasekhar" mass limit — nearly 1.4 times the Sun's mass. Astronomers have two theories of how the white dwarf can get to that mass, and both say that the star must interact with a companion sun of some sort to gain material and reach this limit. This companion has one of two possible identities: It can be another white dwarf or a regular star (like a red giant). In both cases, the two stars were in a binary orbit with each other long before one (or both) became a white dwarf, and likely since they were born. (Due to the extreme vastness of space, two disconnected stars randomly colliding with each other would be an incredibly rare occurrence.)

In the case of two white dwarfs, the two stars spiral closer and closer, giving off gravitational radiation, until they collide. If their combined mass is greater than the Chandrasekhar limit, the collision will result in a type Ia supernova.

In the case of one white dwarf and a regular star, as the stars evolve and begin to spiral closer to each other, they reach a point where mass transfer begins. The white dwarf's gravity is very strong, and the outer layers of the regular star are not tightly bound, so the white dwarf is able to pull gas from the regular star onto its surface. **This mass transfer stabilizes the orbit so that the two stars no longer move closer to each other and will not collide, as in the case of the two white dwarfs.** Instead, the white dwarf can accumulate so much

The most distant galaxy observed (UDFj–39546284, from 480 million years after the Big Bang)



A mature spiral galaxy within the Coma cluster (NGC 4911, some 320 million light-years from Earth)

UDFj-39546284: NASA/ESA/G. Illingworth (University of California, Santa Cruz)/R. Bouwens (University of California, Santa Cruz, and Leiden University)/HUDF09 Team; NGC 4911: NASA/ESA/The Hubble Heritage Team (STScI/AURA)

Galaxy complexity and evolution varied over the history of the universe. In early eras (left), the cosmos was much denser, so protogalaxies — small clumps of dark matter and gas — could form more quickly. These small protogalaxies merged and became more massive, eventually forming the large galaxies of today (right), which also contain richer details and structure than the first galaxies.

mass from its companion that it reaches the Chandrasekhar mass limit and explodes as a type Ia supernova, leaving its companion star behind. If we don't find a star near the supernova remnant's center, we can assume the explosion came from two white dwarfs.
— Ashley Pagnotta, Louisiana State University, Baton Rouge

STAR-CITY FORMATION

Q: The Hubble Space Telescope found a galaxy that was completely formed within 480 million years of the Big Bang. How could gas and dust clouds condense into stars and organize themselves via gravity into an entire galaxy in less time than it takes the Milky Way to make two rotations? **— Mike Palmer,** Kitchener, Ontario, Canada

A: Galaxies like the Milky Way indeed could not have formed as a unit at such an early era after the Big Bang. The time span for sufficient dark matter and gas to collect into a unit bound by gravity and with active star formation would be too long.

So what do we think happened in these early times? The universe was much denser (likely by a factor of more than 1,000) when dark matter began to make the first seeds of galaxies. **The first galactic objects were smaller and denser than present-day galaxies, and thus could collapse and pull in gas on timescales of tens, rather than hundreds, of millions of years. Once gas compressed inside such a protogalaxy, stars could begin to form — an especially tricky step that is not fully understood — and then galactic evolution could proceed quickly.** For example, very massive stars burn their nuclear fuel in less than 3 to 5 million years and explode as supernovae, spewing out newly synthesized atomically heavy chemical elements. These "metals" foster gas-cooling and, thus, more star formation — and the protogalaxy is up and running.

The dense dark matter needed to promote collapse was produced by disturbances in the early universe. As the post-Big-Bang cosmos cooled, the uneven density of dark matter became important: The densest places were first to resist cosmic expansion and collapse under their own gravity. We do not see these protogalactic seeds today. Over time, most of these early objects merged with their neighbors and became more massive, eventually being incorporated as small parts of the giant galaxies we observe today — like the Milky Way.
— Jay Gallagher, University of Wisconsin-Madison

COULD DARK MATTER BE ...

Q: Is it possible that the gravitational effects attributed to dark matter could be caused by Jupiter-sized planets discovered orbiting other stars and also floating freely outside planetary systems? **— Martin J. Grumet,** Boise, Idaho

A: The current number of detected Jupiter-sized planets either gravitationally bound to a central star or free-floating is large, and the count is increasing. The gravitational effects of these worlds on other planets could be substantial, but for the most part such dynamic interactions are confined to their nearby environs.

Ordinary, or baryonic, matter — like the material from which these planets form — interacts with photons to produce scattering, emission, or absorption against luminous sources. Dark matter, which is composed of nonbaryonic subatomic particles, does not interact with light in the same fashion.

A large number of detected and undetected Jupiter-sized planets could not mimic the gravitational effects produced by dark matter for two reasons. First, planets, although faint, are made of luminous matter and therefore are ultimately detectable. Second, their estimated numbers and locations, primarily around the galactic plane, do not support the large-scale gravitational effects similar to those of dark matter (like the ones explaining galactic rotation or the large-scale bending of light, called gravitational lensing).

Given the proper geometric alignment, however, Jupiter-sized planets could produce localized and temporary signal increases from background sources, a phenomenon known as the microlensing effect. This is precisely the mechanism by which we first detected free-floating planets.
— Mario Perez, NASA Headquarters, Washington, D.C.

Send your questions via email to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

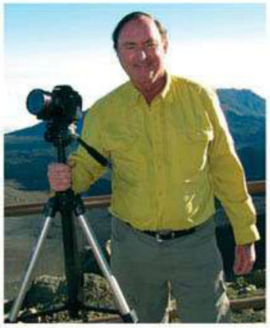
Imaging heaven & Earth

Astrophotographer **Wally Pacholka** *has made an art of capturing amazing landscapes and skies.* **All photos by Wally Pacholka**

During the wee morning hours of a Canadian winter day in 1958, my parents heard again a mysterious sound on the roof. Eventually, my dad went to check what was going on. Finding me on the second-story fire escape, he asked, "What are you doing, Wally?" I answered, "Dad, I enjoy looking at the stars! Don't you?"

My dad didn't know what to make of the whole situation, but my parents soon discovered that their son had a strong interest in the stars and planets. A few years later, with paper route money, I purchased a camera at a pawn shop and began to show my parents and six brothers and sisters — who all thought I was "some kind of nut" — photos of the things I was seeing in the night sky while they slept. My equipment was pretty basic: a 35mm camera, standard 50mm lens, and a tripod. I'd been taking exposures of about 30 seconds.

Today, many decades later, I still use a 35mm camera (a Canon 5D DSLR) with a tripod, slightly shorter exposure times, and no lens with a focal length longer than 50mm. But now, amazingly, my photos are for sale in the gift shops at Palomar Observatory in California, the Keck Observatory on Hawaii's Mauna Kea, Kitt Peak National Observatory in Arizona, and throughout the Western national parks. They've appeared in publications like *Astronomy*, *National Geographic*, and *TIME* magazine, as well as online at NASA's Astronomy Picture of the Day. For 10 years now, taking star photos has gone from being my lifetime hobby to granting me a career as a "professional amateur astronomer."



Wally Pacholka

Landscape love

From the onset, I always liked the idea of capturing both the night sky and the terrestrial landscape in a single shot. This method was just a simple extension of how I naturally saw the night sky with my unaided eyes. We don't see the Big Dipper in the sky by itself; we see it over the neighbor's house or rising above a lake. This technique, self-taught by countless amateur astronomers the

Taking star photos has gone from being my lifetime hobby to granting me a career as a "professional amateur astronomer."

Wally Pacholka *is a member of the international astrophotography team The World at Night (TWAN). His specialty is shooting the national parks at night. For more information, visit www.astropics.com.*

The Milky Way stretches from the Southern Cross (at right) to the Northern Cross in this shot from Hawaii's Mauna Kea.

Orion the Hunter rises over Utah's famous Rainbow Bridge National Monument on Lake Powell (arch lit by flashlight).

Lessons learned

Over the years, I've learned a thing or two about landscape astrophotography. Here are a few tips that you might find helpful, though you should never be afraid to experiment and discover for yourself what works best in a particular situation.

■ **Location, location, location.** If you want to take beautiful photos, you must go to beautiful places. Staying home and shooting the stars between the telephone wires in your backyard won't get your photos into *TIME* magazine or a national park's gift shop.

■ **Take care in composing the shot.** Capture interesting features in both the night sky and on the ground. That way you get a double win.

■ **It might be easier than you think.** Sometimes it all comes down to having the guts to get out there and do whatever it takes to get that one-of-a-kind shot. Today's digital cameras are light-years ahead of anything offered just a short time ago, and it's possible to do today in 10 minutes what took me 10 years to learn.

■ **Know your equipment.** All of today's cameras have a zillion settings in auto mode, but only four settings in manual mode: exposure, f/stop, ISO, and focus. Start by setting your camera to manual mode and trying a 30-second tripod-mounted exposure. If that doesn't work, experiment with different times until you get pinpoint stars. Use the widest f/stop to get the most stars, but if they look like seagulls, cut back the f/stop until they appear sharp again. An ISO of 1600 works well on most cameras, but if it doesn't on yours, work to find your camera's sweet spot. The proper focus is easiest of all to determine: The stars are more than 200 feet (60 meters) away, so just use the infinity setting.

■ **Learn the essentials of photographic techniques.** To summarize: For a film camera, try something like

— Continued on page 56

Mars shines over a rare moonbow from Hawaii's Haleakala Crater.

From the onset, I always liked the idea of capturing both the night sky and the terrestrial landscape in a single shot.

world over, is now officially known as landscape astrophotography.

After my dad moved the family to Southern California in 1965, my night sky easy-access viewing was gone. But despite living in the bright Los Angeles area, I soon discovered the beauty of the local deserts, along with the value of nearby national parks (such as Joshua Tree and the Mojave National Preserve).

As filmmaker and historian Ken Burns says, our country's national parks are "America's gift to itself." This is particularly true for amateur astronomers, as the parks, especially the ones in the West, offer unparalleled beauty and pristine dark night skies. The combination of heavenly and earthly delights is unbeatable for landscape astrophotography.

Safety first

Doing what I do is rewarding and fun, but it's not always easy or safe — kind of like the icy rooftop night-sky

The Milky Way looms over Palomar Observatory in California. Here, the landscape is lit by surrounding cities hidden behind clouds.

Starkweather Lake in the Mammoth Lakes region of California's Eastern Sierra National Preserve reflects Jupiter and the stars of the Milky Way.

Old Faithful erupts in Wyoming's Yellowstone National Park (illuminated by local hotel parking lights).

Sequoia National Park in California boasts a view featuring Venus, Orion, and their reflections in Hume Lake.

Lessons learned

— Continued from page 54

Fuji 800 film, with a 30-second exposure, as near to f/2 as possible, and a 50mm, 35mm, or 24mm lens (no zoom lenses, which are generally not fast enough). This will record every star visible to the unaided eye. I left my film camera behind in the past century and now use a digital camera, setting the ISO to 1600, the f/stop to f/2.2, and taking a 25-second exposure through a 24mm lens or a 20-second exposure with a 35mm lens.

■ **Lighting is critical in any good photograph.** If you want your foreground subject to be visible and not appear as a silhouette, then you must figure out a way to light it. Unless the composition features nearby city lights (as in my Palomar Observatory picture at the top of page 55), you should get your shooting schedule to coincide with a crescent Moon, so it can light up your foreground (as in my Devils Tower photo at right). One approach I use is illuminating close foreground objects like rocks or hills with a flashlight while taking the star shot (as in my Rainbow Bridge shot at the bottom of page 53).

■ **Embrace the power of panorama.** Perhaps the most powerful tip I can offer is to transform your 12-megapixel 35mm camera into a 100-megapixel tool simply by shooting a panoramic sequence of side-by-side shots. Each one should include both the sky and land as you cover the entire horizon before you. Then, you can stitch the individual shots together using digital panoramic software.

■ **Above all else, have fun!** No one is born a perfect photographer, so just go out and capture whatever you're most passionate about. I have discovered that I am really good at going to great lengths to be in the middle of nowhere in the middle of the night with no one else around. Whether it's on an icy rooftop or in a national park, I see it as my mission to show others the beauty I find there. — *W. P.*

A monster Geminid meteor streaks over the Mojave Desert in California.

Devils Tower National Monument in Wyoming, lit by moonlight, stands before the Milky Way.

viewing that my dad had to put a stop to. In order to photograph national park landmarks at night, I need to actually hike the parks at night, usually alone. (After all, who would be crazy enough to join me as I drive 500 miles [800 kilometers] to one location, shoot all night, and then go 300 miles [500km] to the next location?)

Folks say I should write a book about my nighttime close encounters, which include bears, snakes, large cats, small cats, skunks, porcupines, bugs, tarantulas, bears, unknown creatures walking in the shallow water toward me, green eyes looking at me from the darkness, and did I mention bears? Add in the fun of getting lost about a

The sky over Hawaii's Haleakala Crater at sunrise reveals Scorpius, Alpha (α) and Beta (β) Centauri, and the Southern Cross.

The Milky Way rises over California's scenic Manzanita Lake in Lassen Volcanic National Park.

Despite living in the bright Los Angeles area, I soon discovered the beauty of the nearby deserts.

zillion times, and it's clear some nights will be a little bit more exciting than others.

My most unforgettable experience was on a shoot at one of the darkest sites on Earth, imaging the stars with my associate Babak Sedehi over the huge Moai stone statues on Chile's Rapa Nui (Easter Island). It was just past midnight, and I had two cameras going; I manually took close-ups of the statues with one and had the other automatically taking 30-second shots of the whole area from about 50 yards off. Suddenly, out of the distant darkness, we heard something shouting, "Furo! Furo! Furo!" We looked up to see a frightful, tattooed, nearly naked figure walking toward us throwing stuff.

We didn't know what he was saying, but Babak got the message loud and clear, and he screamed at me, "Run! Wally, run!" Babak ran straight for the car, which was about 300 yards away, but I had to grab all of my scattered gear. I fell once but managed to keep going as our assailant's projectiles landed nearby.

Babak had the car running (he was in full getaway mode) and swung the door open for me as I arrived. But, because I was carrying two camera tripods with six legs going every which way, I had trouble getting in.

Finally, I forced my way through. Unfortunately, a tripod leg kept the door open, and I almost flew out as Babak rounded the first corner. Both of us were scared out of our wits until the bed and breakfast manager calmly told us, "Oh, that's Fetu. He's the assigned security guard out there!"

See more of the author's wide-field imagery online at www.Astronomy.com/toc.

Explore the Summer Triangle

Although you'll never see Mars within the area bounded by these three bright stars, you can explore double stars, nebulae, and star clusters. **by Michael E. Bakich**

From June through October in the Northern Hemisphere, the three stars of the Summer Triangle ride highest. Top dog is Vega (Alpha [α] Lyrae), the fifth-brightest star in the night sky. At magnitude 0.03, it has long been astronomy's standard zero-magnitude star. Altair (Alpha Aquilae), the 12th-brightest star, glows with half Vega's output at magnitude 0.77. Last, but only least when compared to its two companions, magnitude 1.25 Deneb (Alpha Cygni) comes in as the 19th-brightest star, one-third as bright as Vega.

The region bounded by the Summer Triangle contains enough deep-sky treats to keep you observing for many hours. Let's examine a few of them.

Start in the Harp

Begin by pointing your telescope midway between Sheliak (Beta [β] Lyrae) and Sulaphat (Gamma [γ] Lyrae) to find the **Ring Nebula** (M57). Through a 4-inch telescope, you'll see the Ring as a pale gray ball 71" across with a magnitude of 8.8. If you use a magnification above 100x, you'll notice that the ball's outer part looks thicker than the central region. This gives M57 its distinctive "ring" appearance.

Even for large-scope users, spotting M57's central star ranks as a difficult observing challenge. With a 16-inch or larger instrument on a night of excellent seeing, use an eyepiece that yields between 300x and 400x. Keep in mind that you're searching for a 15th-magnitude star against a background that's not completely dark.

The Ring Nebula (M57) in Lyra shows the outer layers of a Sun-like star puffed off in the late stages of its life. Mark Hanson

If the central star doesn't show itself immediately, lightly tap on the tube. Because the eye is sensitive to motion, you may spot the central star at this point.

You'll find the next object a bit more than 5.5° east-southeast of M57. It's globular cluster **M56**, which, at magnitude 8.4, shows up in binoculars from a dark site.

Through a telescope, the density of stars in M56 increases dramatically as you move toward its core. And because the individual cluster stars aren't all that bright, you'll resolve them best through 8-inch or larger telescopes and at magnifications exceeding 150x. When you're done examining the inner workings of M56, back off the power and enjoy the star field this cluster is in.

Now target Delta (δ) Lyrae to observe the open cluster **Stephenson 1**, also known as the Delta Lyrae Cluster. This is a pretty sight through even a 3-inch scope. Powers around 50x will split the standout suns in this cluster, Delta^1 and Delta^2 Lyrae, easily. The former is a blue magnitude 5.6 star while its companion (some 10' away) is an orange luminary shining at magnitude 4.5. The rest of the cluster counts 50 stars of various brightnesses.

Our last object in Lyra is the gorgeous open cluster **NGC 6791**, which lies less than 1° east-southeast of magnitude 4.4 Theta (θ) Lyrae. Its diameter of 15' — nearly half that of the Full Moon — means that, even at magnitude 9.5, NGC 6791 appears faint through small scopes. In fact, you may be fooled into thinking it's a globular cluster.

Through 12-inch and larger instruments, NGC 6791 begins to strut its stuff. Dozens of faint cluster stars begin to resolve into a fine, evenly distributed pile of diamond dust.

Explore Cygnus

In the center of the Summer Triangle, you'll find **Albireo** (Beta Cygni), one of the sky's finest double stars through any size telescope. The primary star shines golden at magnitude 3.4 while its companion glows sapphire-blue at magnitude 5.2. A healthy 35" separate the two.

The Crescent Nebula (NGC 6888) reveals the interaction between a cloud of gas and a star's radiation and stellar wind. Ken Crawford

Our next object, the **Crescent Nebula** (NGC 6888), is a bubble of gas carved out of the interstellar medium by an energetic sun called a Wolf-Rayet star, after the two astronomers who identified the type. It shines at 7th magnitude at NGC 6888's center. The Crescent lies 1.2° west-northwest of the magnitude 4.8 star 34 Cygni.

Although you'll spot the Crescent Nebula through small scopes, 8-inch and larger instruments begin to show some of its structure. The slightly curved northwestern edge is the brightest, but a short line of bright nebulosity also lies to the southwest.

From the Crescent, move a bit more than 2° east to **M29**. Although this target is a Messier object, it's one of the most difficult to identify. The reason is that M29 is a loose open cluster of about two dozen stars lying in front of a rich Milky Way star field.

To find it, look 1.8° south of magnitude 2.2 Sadr (Gamma Cygni). A small telescope

Michael E. Bakich *is an* Astronomy *senior editor and author of* 1,001 Celestial Wonders to See Before You Die *(Springer, 2010).*

The Dumbbell Nebula (M27) has a high surface brightness, so even small-telescope owners can enjoy it. Joe and Gail Metcalf/Adam Block/NOAO/AURA/NSF

works best on this cluster because it won't reveal the multitude of surrounding stars. To prove this to myself, I once made a cardboard insert for the front of a 12-inch telescope. The insert had a 3-inch-diameter hole in it, which I had carefully cut out. I viewed M29 with and without the insert, and the cluster was, indeed, easier to pick out when the insert was in place.

Poor Aquila

Because the Summer Triangle's stars come from three constellations, you should assume that Aquila brings something to the table. Alas, such a small area of the Eagle lies within the triangle that we can attribute no deep-sky treats to this constellation.

Still, I didn't have the heart to totally exclude Aquila, so, ever-so-slightly outside the bounds of the triangle, look for one of my all-time favorite binocular objects. **Barnard's E**, a combo of two dark nebulae from American astronomer Edward Emerson Barnard's famous catalog, lies against the rich Milky Way. Start at yellow magnitude 2.7 Tarazed (Gamma Aquilae). If you center that star, you shouldn't have to move your binoculars at all. Barnard's E lies 1.4° to the west-northwest.

Barnard 143 (often designated B143) is the easiest of the pair to spot. It's a narrow bar about 15' long, oriented east-west. Two slightly less distinct dark bars connect to it and form a U shape. Just to the south lies Barnard 142 (B142), another dark nebula not quite as long and only one-third as wide, making it more difficult to see. Behind these dark clouds, you'll see the light of thousands of unresolved stars.

Bonus entries

The three constellations already discussed don't completely cover the area of the Summer Triangle. In fact, you'll find half of Vulpecula the Fox and almost all of Sagitta the Arrow in our chosen area.

Our next object is an easy one to spot through binoculars. Extend a line southward from Albireo in Cygnus through magnitude 4.4 Alpha Vulpeculae. That distance is roughly 3°. Head 4.5° farther south, and you'll encounter Collinder 399.

This group was the 399th entry (out of 471) in a catalog of open clusters compiled by Swedish astronomer Per Arne Collinder. Its most common name, the **Coathanger**, comes from its shape.

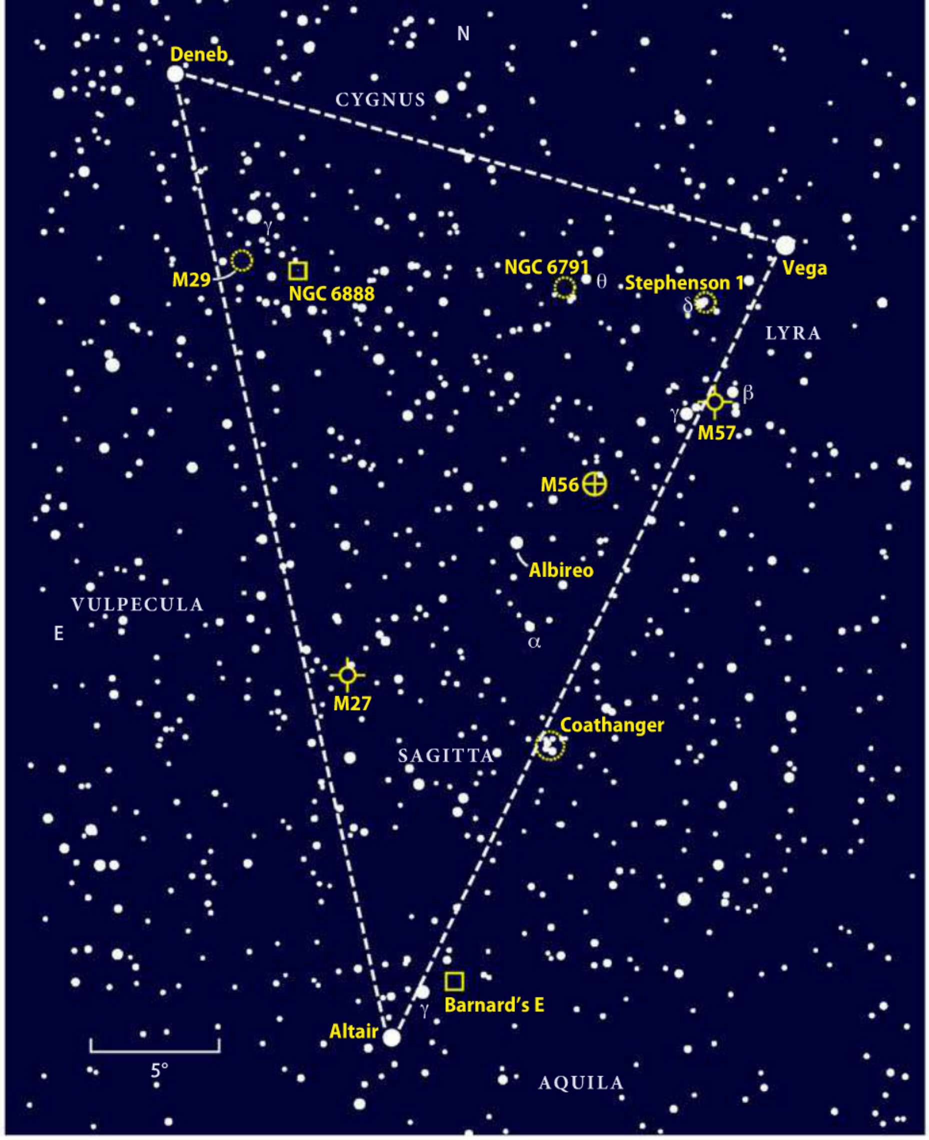
Because it's so big, the Coathanger looks best at magnifications of 20x or less. Ten stars glow brighter than 7th magnitude, so the group appears as a distinct glow to the naked eye on dark nights. The brightest are 4 Vulpeculae, at magnitude 5.1; 5 Vulpeculae, at magnitude 5.6; and 7 Vulpeculae, which shines at magnitude 6.3.

For my final object, I'd be hard-pressed to leave out the **Dumbbell Nebula** (M27), a great object for small-scope owners. You can find it by drawing a line from Altair to Sadr. M27 lies slightly less than halfway from your starting point.

M27 owes its common name to a double-lobe shape common among planetary nebulae. Even through binoculars, this object is easy to spot. To see details in it, however, set up your telescope.

A 4-inch scope shows the two bright lobes and several stars scattered across M27's face. This object responds well to high magnifications because it has a high surface brightness. Use a large telescope with an Oxygen-III filter and really crank up the magnification.

After a night or two hunting objects within the Summer Triangle, you'll see those three stars in a whole new light.



Use this finder chart to locate all the objects discussed in this story. *Astronomy*: Richard Talcott and Roen Kelly

To see additional images of deep-sky objects in the Summer Triangle, head to www.Astronomy.com/toc.

20 best dark-sky sites in the U.S.

Searching for a place to set up your telescope? A top-notch location might be closer than you think.
by Michael E. Bakich

Die-hard amateur astronomers aren't the only ones who want a dark observing site. It could be that you recently purchased your first telescope, and you're dying to know how well it can perform under optimal conditions. Unfortunately, you live in a metropolitan area where just catching the Moon in the sky is an accomplishment. Take heart! As this map shows, you'll find great observing locations throughout the contiguous United States.

Some are the sites of star parties, three- to nine-day annual events where amateurs — as well as the public — gather under a dark sky. Others are sites managed by and for local astronomy clubs. Become a member and you'll gain immediate access to a dark site. Still others are communities set up specifically for amateur astronomers where you can lease or purchase lots.

Whichever location you choose, you will experience a great limiting magnitude (the faintest star you can see) and good seeing (the steadiness of the atmosphere above you). Just remember to check the weather forecast before you go. No site is good enough to overcome clouds.

Michael E. Bakich *is an* Astronomy *senior editor who has observed at most of the sites on this map (and lots more).*

1 Cherry Springs State Park
Location: near Galeton, Pennsylvania
Open: year-round
Hosts: the Cherry Springs Star Party; the Black Forest Star Party; Music and Stars programs featuring concerts followed by an hour of stargazing (requires admission fee); free public programs
Note: The International Dark-Sky Association named it the second International Dark Sky Park on June 11, 2008.
[w] www.dcnr.state.pa.us/stateparks/findapark/cherrysprings

2 Green Bank Star Quest
Location: Green Bank, West Virginia
Open: once a year for a four-night star party
Note: Organizers bill the Star Quest as the largest optical and radio star party in the nation. Registration includes campsite and shower facilities.
[w] www.greenbankstarquest.org

3 Deerlick Astronomy Village
Location: Sharon, Georgia
Open: to individuals who buy an annual field membership; 1.5-acre plots for cabins or houses are available on these 96 acres
Hosts: the Peach State Star Gaze
Note: As of this writing, only four sites remain available.
[w] www.deerlickgroup.com

4 Chiefland Astronomy Village
Location: 7 miles south of Chiefland, Florida
Open: to members, and to visitors approximately 10 days per month for $5 per night
Hosts: the Chiefland Star Party
[w] www.chiefland.com/chieflandastronomyvillage.php

5 Winter Star Party
Location: on Scout Key in the Florida Keys
Open: once a year for a weeklong star party
Note: This location has the most southerly latitude — 24°38'58.2" — of any dark-sky site on this map. From here, Acrux (Alpha [α] Crucis), the southernmost bright star in Crux the Southern Cross, sits right on the horizon, and the globular cluster Omega Centauri (NGC 5139) stands 18° above the southern horizon at its highest.
[w] www.scas.org/wsp.html

6 Great Lakes Star Gaze
Location: River Valley RV Park in Gladwin, Michigan
Open: once a year for a four-day star party
Note: In addition to sites at the RV park, you'll find available lodging at five nearby locations. Registration discounts are available to those signing up before the posted deadlines.
[w] www.greatlakesstargaze.com

7 Hobbs Observatory
Location: Beaver Creek Reserve near Fall Creek, Wisconsin
Open: year-round to members of the Chippewa Valley Astronomical Society (CVAS) and guests
Hosts: the Northwoods Starfest, a three-day event in late summer
Note: The CVAS conducts monthly club meetings (except during December) that include programs and observing and are open to the public.
[w] www.cvastro.org/events.htm

8 Heart of America Star Party
Location: near Butler, Missouri
Open: once a year for a five- to seven-day star party
Note: hosted by the Astronomical Society of Kansas City
[w] www.hoasp.org

9 Nebraska Star Party
Location: Snake Campground, Merritt Reservoir, 27 miles south of Valentine, Nebraska
Open: once a year for a weeklong star party
Note: A Nebraska State Park entrance permit ($4 per day; $20 per year) is required on all vehicles entering the observing field. A $7 per day fee also is required if you are camping in the park.
[w] www.nebraskastarparty.org

10 Okie-Tex Star Party
Location: Camp Billy Joe, 1 mile east of Kenton, Oklahoma
Open: once a year for a nine-day star party
Note: The event is hosted by the Oklahoma City Astronomy Club. The club allows school groups that preregister to attend.
[w] www.okie-tex.com

11 Rocky Mountain Star Stare
Location: private land roughly 6

Background: iStockphoto/Thinkstock; map: *Astronomy*: Roen Kelly

miles north of Gardner, Colorado
Open: once a year for a five-day star party in June or early July
Note: The Colorado Springs Astronomical Society hosts this event, which features speakers, kids' activities, door prizes, and more.
[w] www.rmss.org

12 Texas Star Party
Location: Prude Ranch, 5 miles north of Fort Davis, Texas
Open: once a year for a weeklong star party
Note: Prude Ranch offers tent camping, trailer/RV sites, bunkhouses that sleep eight to 20, and family cabins that sleep two to four. Because of high demand, organizers of the Texas Star Party conduct a random drawing in January to choose that year's actual attendees.
[w] www.texasstarparty.org

13 Double U Ranch
Location: near Cornudas, Texas
Open: year-round to members and guests of the Sun City Astronomers (SCA)
Note: The SCA meets monthly in the Gene Roddenberry Planetarium, 6531 Boeing Drive in El Paso.
[w] http://tech.groups.yahoo.com/group/suncityastronomy

14 Enchanted Skies Star Party
Location: Socorro, New Mexico
Open: once a year for a four-day star party
Note: offers tours of the Karl G. Jansky Very Large Array and a night of observing at the Magdalena Ridge Observatory, which sits atop South Baldy at an elevation of 10,600 feet (3,230 meters)
[w] www.enchantedskies.org

15 Granite Gap
Location: 13 miles north-northwest of Animas, New Mexico
Open: year-round to lessees and for site inspection visits by individuals wishing to lease plots
Note: Leases are available for ⅓-acre plots on which you can park a camper or erect an observatory. Rental units are available for extended stays.
[w] www.granitegap.com

16 Russell Country Star Party
Location: Lewis and Clark Interpretive Center, Great Falls, Montana
Open: monthly on Friday nights closest to New Moon, weather permitting
Note: The Central Montana Astronomy Society, with cooperation from the U.S. Forest Service, hosts these events, which include refreshments, indoor kids' activities, free admission to the Lewis and Clark Center, and more.
[w] www.russell.visitmt.com/listings/15177.htm

17 Grand Canyon Star Party
Location: the North and South rims of Grand Canyon National Park in Arizona
Open: once a year for a weeklong star party
Note: Volunteers set up their telescopes for park visitors. Admission for seven days is $25 per private vehicle or $12 per individual.
[w] www.nps.gov/grca/planyourvisit/grand-canyon-star-party.htm

18 Table Mountain Star Party
Location: approximately 20 miles north of Ellensburg, Washington
Open: once a year in July or August for a three-day star party
Note: You can get to the star party other ways than the directions on its website. Alternate routes, however, are generally suitable only for four-wheel-drive vehicles.
[w] www.tmspa.com

19 Oregon Star Party
Location: Indian Trail Spring in the Ochoco National Forest, 45 miles east of Prineville, Oregon
Open: once a year for a weeklong star party
Note: This star party spreads across 40 acres and offers some of the darkest skies in the country. Organizers develop three observing lists every year, each with an award certificate and pin.
[w] www.oregonstarparty.org

20 Steve Kufeld Astronomical Site
Location: 2.5 acres approximately 90 miles northwest of Los Angeles, California
Open: year-round to members and guests of the Los Angeles Astronomical Society
Note: The site offers 57 concrete pads with power outlets for setting up personal telescopes. Members can purchase one of these pads for a nominal fee.
[w] www.laas.org

Astronomy tests Vixen's compact astroimaging mount

The Polarie Star Tracker makes it easy to take long-exposure wide-field images. **by Tom Trusock**

The Polarie compensates for Earth's rotation by driving a standard ball head mount, which attaches to a camera. An optional tripod from Vixen is available. It costs $249 and comes with two ball heads. All product images: *Astronomy*: William Zuback

With increasing light pollution and gas prices, astroimaging seems to be the up-and-coming trend in the hobby over the past few years. Sites that simply aren't good enough for visual astronomy will still let you produce some great photos with the right combination of gear and know-how. That's because software now allows you to subtract the part of your image that comes from light pollution. Still, there always have been barriers to getting started in astrophotography. The deeper you get into it, the more it's going to cost you.

A mount is the most crucial (and expensive) piece of hardware for an astroimager. When you're picking one, you have to choose between stability (which, for the uninitiated, means large, heavy, and expensive) and portability. You can make things a little easier by choosing to go with a less demanding (but equally stunning) form of celestial photography — wide-field — but the mounts can still be rather bulky.

Product information

Vixen Polarie Star Tracker

Usable: Anywhere on Earth
Tracking rates: Wide-Field Astrophotography, Lunar, Solar, and Star-Scape
Maximum load: 4.4 pounds (2 kilograms)
Power: Two AA batteries or external power supply via mini-USB
Battery life: About 4 hours at 68° Fahrenheit (20° Celsius)
Dimensions: 3.7 by 5.4 by 2.3 inches (9.5 by 13.7 by 5.8 centimeters)
Weight: 1.4 pounds (0.64 kilogram) without batteries
Price: $429
Contact:
Vixen Optics
1023 Calle Sombra, Unit C
San Clemente, CA 92673
[t] 949.429.6363
[w] www.vixenoptics.com

Finish and features

It was to meet this market that Vixen Optics introduced the Polarie Star Tracker — an ultraportable tracking mount designed for wide-field photography and recommended for lenses with focal lengths up to 100 millimeters. You can buy the Polarie separately, but for this review it came bundled as a package with a robust portable tripod designed with imaging in mind, along with two ball heads.

The critical piece of gear, the Polarie, is reminiscent of a DSLR camera body in both size and shape, and it's quite attractive. Vixen placed a sighting hole (with an 8.9° field of view) in the upper corner to help align the unit with the North or South Celestial Pole. As someone used to lying on the ground when using a German equatorial mount (GEM) to observe, I was grateful that the included tripod was tall enough to make polar alignment fairly painless.

On the unit's side, you'll find a tilt meter/inclinometer (with 5° resolution) to get you started with polar alignment. The top has a "mode" dial (more on that in a bit), and even a shoe where you can attach additional accessories. The "front" of the unit sports a removable mounting plate, behind which you'll find a slot designed to attach to the optional polar scope — for those who need a more exact alignment.

The Polarie can run via two AA batteries or by an external 4.4- to 5.25-volt source, and it takes that juice via a mini-USB plug. Vixen states that two AA batteries can run the mount for about four hours

Tom Trusock *is a seasoned skywatcher and techie who observes from Ubly, Michigan.*

The Milky Way **near Antares (Alpha [α] Scorpii) is a favorite wide-field sky target. For this shot, the imager attached his Nikon D700 DSLR with a 105mm Nikon lens to Vixen's Polarie mount. This version combines twelve 5-minute exposures.** John A. Davis

Vixen Optics' Polarie Star Tracker **is a compact mount ideal for wide-field astroimaging with a digital camera.**

with the maximum load of 4.4 pounds (2 kilograms). In practice, I found the time varied between 90 minutes and six hours depending on the temperature and the quality of the batteries used. Imagers need not fear suddenly running out of juice because the power indicator will begin blinking when the batteries get low.

The Polarie has a mounting socket (¼"–20 thread) that will let you attach it to any standard photography tripod. A stepper motor with two bearings drives it, and the Polarie is usable in either the Northern or Southern Hemisphere.

The tripod has four-section legs, a maximum load bearing capacity of 6.6 pounds (3kg), and adjusts from 21.2 to 70 inches (54 to 178 centimeters) high. Collapsed, it measures 22 inches long (56cm) and weighs around 4.3 pounds (2kg) without the (included) pan head. The tripod has a geared center column and attaches using a setup similar to a GEM. This is a great idea as it's a feature that allows you to easily adjust the inclination. It will look familiar to astroimagers but somewhat less so to standard photographers.

Tracking options

The Polarie offers several different tracking modes you select with the mode dial: "Wide-Field Astrophotography" (whose symbol is a star); "Lunar" (symbol is a crescent Moon); "Solar" (a stylized Sun); and "Star-Scape" (the fraction ½). The other setting (Vixen calls it "Preparation" and its symbol is a light bulb) is to assist in polar alignment. Use "Wide-Field Astrophotography" for deep-sky shots where you either won't have a foreground or where the foreground is blurred.

The length of an unguided exposure before you see star trails depends on the focal length of the lens and the declination of your target object. For a DSLR with a 24mm lens imaging a target with a declination of 45°, you can expose for roughly six minutes before star trails begin to show up. The shorter the lens' focal length, or the greater the declination, the longer you can shoot before you run into star-trailing. Alternatively, shooting an object on the celestial equator with a 100mm lens limits you to about a minute of unguided exposure time before star-trailing appears.

"Lunar" and "Solar" modes envision the lengths of their respective eclipses and allow you to track for up to four hours. The "Star-Scape" mode offers something of a compromise setting for folks who wish to shoot the sky and also include the foreground in the frame. If you shoot with your camera still, the foreground will be sharp, but the stars will appear as trails.

Change the tracking mode **by rotating this dial on the top of the Polarie Star Tracker.**

In the "Wide-Field Astrophotography" tracking mode, you'll see sharp stars but a blurry foreground. "Star-Scape" tracks at a slower rate, so it splits the difference between the (apparently) moving stars and the ground beneath them.

The Polarie fits well in my camera bag, taking up no more room than an SLR body. In addition, Vixen's tripod can double as a photographic tripod, further reducing the amount of gear you have to carry. Given the limited amount of packing space on any trip, this is a useful feature.

Wrap one up

The Polarie doesn't have the load-bearing capacity to use as a tracking mount for visual observing, as some might want. What works well for a camera doesn't work so well for a larger telescope with a longer focal length. However, it's not designed for that, and it works superbly for its intended use. The build quality on the Polarie is first-rate, and the functionality is excellent. It weighs little, runs on AA batteries, and will conveniently pack into your luggage.

Vixen has long been known for providing high-quality products at good prices. If you're interested in wide-field astroimaging — say using a lens of focal length 24mm to 85mm — and want an extremely portable setup, the Polarie Star Tracker fits the bill without breaking the bank.

Observing**Basics**

by Glenn Chaple

Accessible astronomy

Having a disability shouldn't prevent anyone from active participation in astronomy.

"Imagine this. You are standing at your telescope waiting for the next interested person to take a peek, when you notice someone in a wheelchair approaching you. All you can think of is 'What should I do?'" (Noreen Grice, *Everyone's Universe: A Guide to Accessible Astronomy Places*, You Can Do Astronomy LLC, 2011)

What would *you* do? Approximately one in five individuals copes with a disability — such as visual and/or hearing impairments, communication challenges, or wheelchair confinement. None of us is immune. An illness, accident, or simply the aging process can leave a once able-bodied person with a disability. And it's quite possible that such an individual will show up at a public star party you or your club is conducting.

Having a disability shouldn't prevent anyone from active participation in astronomy. In fact, many have overcome handicaps to make notable astronomical contributions. In 1783, astronomer John Goodricke, who was deaf/mute, was awarded the Copley Medal by the Royal Society of England for his work on variable stars. Until 1932, Edwin Frost was both director of Yerkes Observatory in Wisconsin and editor of *The Astrophysical Journal* despite having become blind 11 years earlier. Blindness is no hindrance to modern-day astronomers — for example, Wanda Diaz-Merced, though blind, is an active radio astronomer with NASA's Goddard Space Flight Center in Maryland and a Ph.D. student at the University of Glasgow in the United Kingdom.

But perhaps the most celebrated astronomer (well, physicist) with a mobility and communications disability is Stephen Hawking. Despite being confined to a wheelchair and dependent on a computerized voice system to speak (a result of having contracted Lou Gehrig's Disease), Hawking has used his mathematical genius to probe some of cosmology's greatest mysteries.

Browse the "Observing Basics" archive at www.Astronomy.com/Chaple.

Everyone's Universe: A Guide to Accessible Astronomy Places, **by Noreen Grice, explains how to help everyone see and enjoy the universe.**

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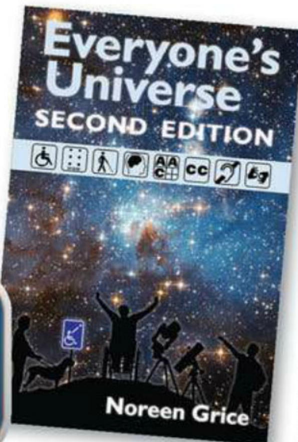


Noreen Grice

Modern technology has brought research astronomy into our homes — a boon to individuals with disabilities. Computer users with mobility or hearing problems can access robotic telescopes or work on Internet projects like Zooniverse's Galaxy Zoo, Moon Zoo, and Planet Hunters. To support the upcoming Lunar Atmosphere and Dust Environment Explorer mission, NASA is asking volunteers to make meteor counts using FM radio receivers. Find details of this project, a nice fit for visually impaired space enthusiasts, at http://lunarscience.nasa.gov/articles/radio-meteor-counts.

But back to the original question. What would you do should a person in a wheelchair approach you at a star party? Noreen Grice has some ideas. She became an advocate of astronomy for visitors with disabilities after a planetarium show she conducted for a group of children who were blind. An assessment of the program according to the kids? "It stunk!"

Spurred by the incident, Grice began to research strategies for presenting astronomy to individuals with a variety of disabilities. Ultimately, she established You Can Do Astronomy LLC — a company whose mission is to make astronomy and space science accessible to people of all abilities. Her book *Everyone's Universe: A Guide to Accessible Astronomy Places* is a must-read for anyone involved in astronomy outreach and should be in the possession of every astronomy club and science facility.

Everyone's Universe is designed to educate both astronomy clubs and participants with disabilities. Suggestions for accessible outreach efforts include eyepiece extenders for those using wheelchairs, tactile books like Grice's *Touch the Stars* (National Braille Press, 2002) for readers who are visually impaired, picture boards to assist individuals with communication challenges, and simple paper and pen or iPad to interact with a person who cannot hear. *Everyone's Universe* also provides a state-by-state listing of accessible astronomy facilities, such as planetariums and observatories.

But why wait for a person with a disability to show up at your star party? Be proactive and organize an accessible star party in your community! In *Everyone's Universe*, Grice spotlights Project Bright Sky, developed by the Pomona Valley Amateur Astronomers (PVAA) in California. Through this project, the PVAA conducts private star parties for those who are visually impaired and offers tactile astronomy classes at local Braille institutes. For more on You Can Do Astronomy and Project Bright Sky, visit www.youcandoastronomy.com and http://brightsky.pvaa.us, respectively.

As we strive to infuse the excitement of astronomy into the public, we mustn't neglect the 20 percent of the population suffering from some kind of disability. Who knows? That person approaching your telescope might be a potential contributing member of your astronomy club, possibly even a future scientist. You can help make the universe more accessible!

Questions, comments, or suggestions? Email me at gchaple@hotmail.com. Next month: some lunar letters. Clear skies!

This article is dedicated to Ellie Isaacs, whose pen-on-paper rendering of Stephen Hawking appeared on page 10 of the May 2012 issue of Astronomy *magazine.*

Imaging the Cosmos

by Tony Hallas

"HDR Toning," part 2

Learn how to tweak the details in your images to achieve a fantastic look.

In my previous column, I went over the basic controls of Adobe *Photoshop CS5*'s "High Dynamic Range (HDR) Toning." Now, it's time to fine-tune.

To fully understand HDR, it helps to know why it was invented. As digital imaging evolved, it became easy to capture information beyond what a single frame can depict. When *Photoshop* creates a huge 32-bit image — by combining data from the deepest shadows to the brightest highlights — a problem arises. How do you bring all these tonal values down to a more limiting 16- or 8-bit image without losing too much detail? If we could go into this huge image and enhance the *local* detail elements in it, then when we reduce bit depth (and lose data), the major detail will still be there after the loss.

It turns out this same idea applies to well-made astroimages, which possess good detail from the shadows to the highlights. The better the data you start with, the more "HDR Toning" can do for your image. It will analyze your image and attempt to enhance the subtle detail through the process of "local micro contrast enhancement." Let's examine the HDR controls more closely.

First of all, know that whenever you process an astroimage in HDR, the highlights are likely to wash out right away. Not to worry: the "Gamma" and "Highlight" sliders under "Tone and Detail" work well together to bring them back. It's helpful to have your first step be simply using both sliders to make the highlights look normal again.

The "Radius" setting under "Edge Glow" works similar to the "Radius" setting in "Unsharp Masking," another image manipulation technique: Selecting smaller pixel amounts emphasizes the fine detail, while working with large numbers of pixels emphasizes the overall image. I usually leave the "Strength" of "Edge Glow" around 0.50, unless the image is unresponsive.

It's easy to overprocess your photos with this powerful tool. Your goal is to maintain the "natural" look of each image for the best results.

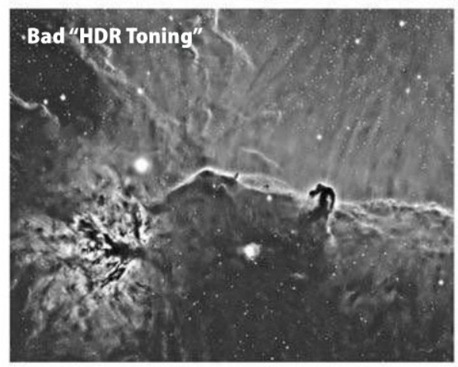
"Detail" (also under "Tone and Detail") is like a multiplier of the "Edge Glow" effect. Watch what happens when you set the "Edge Glow" "Radius" slider to different settings while moving the "Detail" slider back and forth. Remember, this is a powerful setting, and it requires discretion. You want to enhance the detail in your image, but not make it obvious how you did it.

Once you are satisfied with your settings, go back and fine-tune the "Gamma" and "Highlight" settings one last time. You want as much "Gamma" (midrange contrast) as your image can support while working in conjunction with the "Highlight" slider to keep the image's highlights from blowing out.

One of the side effects of "HDR Toning" is emphasizing the noise structure, or visual static, along with the other detail in your image. To fix this, simply use a mild noise reduction application such as *Neat Image* or *Noise Ninja* afterward — and possibly before, if your image is noisy to begin with. Excessive noise can "distract" the HDR software from the image's true tonal values. It bears repeating that it's easy to overprocess your photos with this powerful tool. Your goal is to maintain the "natural" look of each image for the best results.

"HDR Toning" may seem intimidating at first, but if you experiment with the controls, it will soon start to make sense. (For more details, visit www.astrophoto.com.) In other words, the best way to understand HDR is to use it!

Browse the "Imaging the Cosmos" archive at www.Astronomy.com/Hallas.

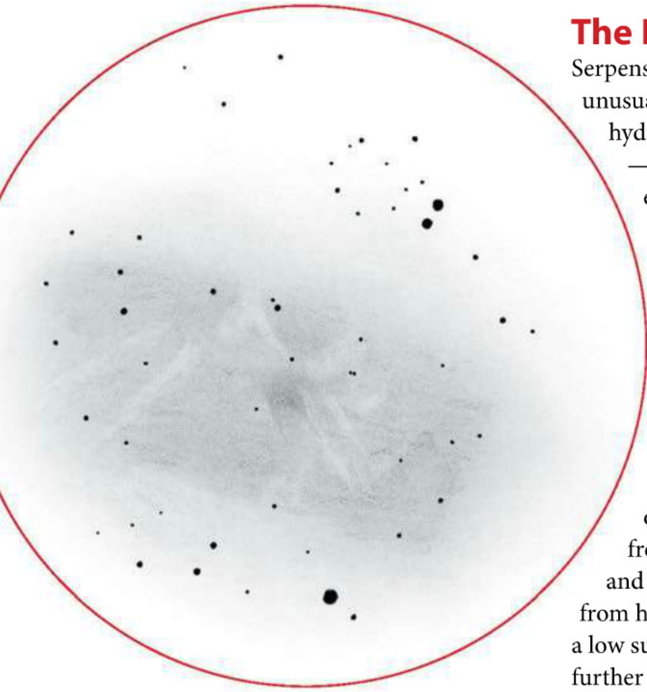


The Horsehead Nebula appears here after basic processing but before "High Dynamic Range (HDR) Toning" (top), after good use of "HDR Toning" (middle), and after too much HDR use. It can be easy to overdo it, leaving an astroimage looking stark and unnatural, but correctly using "HDR Toning" can improve an already great image. Tony Hallas

Deep-sky Showcase

Astronomy's editor sketches two of his favorite objects. **by David J. Eicher**

The Eagle Nebula and NGC 7023



The Eagle Nebula sketched by David J. Eicher using an 8-inch f/10 Celestron SCT at 70x.

The Eagle Nebula (M16)

Serpens Cauda contains one of the most unusual and complex regions of ionized hydrogen in our galactic neighborhood — the Eagle Nebula (M16). This large emission nebula is centered on a bright star cluster containing 60 stars of 8th magnitude and fainter in an area 25' across. The star cluster makes for a fine binocular sight and, at 6th magnitude, is just visible to the naked eye from a relatively dark site.

M16's star cluster is bright and easy to see; the challenging aspect of this object is to spot the glow from the gas that produced the cluster and now fluoresces under strong gusts from hot stellar winds. The nebulosity has a low surface brightness, and its visibility is further hindered by the presence of several bright stars in the field; through an 8-inch scope at low power, it appears as a milky, greenish-gray light. Larger scopes show more nebulosity, channels of dark nebulae interlaced throughout, and the dark globules that are collapsing into protostars. The nebula's low surface brightness means observing it on a moonless night is essential; it also makes it difficult to use high magnifications. A good nebula filter often helps with contrast, making the faint outlines of the Eagle easier to see.

M16

Bob Fera

Designations: M16, NGC 6611
Position: 18h19m, –13°48' (2000.0)
Constellation: Serpens Cauda
Magnitude: 6.0
Size: 35' by 28'
Distance: 5,600 light-years

NGC 7023

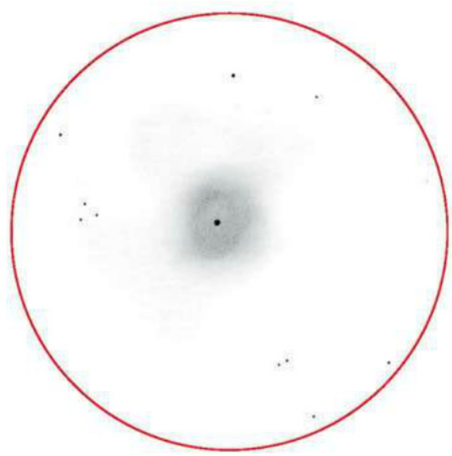
Adam Block/Mount Lemmon SkyCenter/University of Arizona

Designation: NGC 7023
Position: 21h02m, 68°10' (2000.0)
Constellation: Cepheus
Magnitude: 6.8
Size: 18'
Distance: 1,300 light-years

NGC 7023

The west-central portion of the constellation Cepheus holds an unusual object — the faint reflection nebula NGC 7023, sometimes called the Iris Nebula. Most glowing gas clouds in the sky shine through the process of ionization — excited atoms kick off a photon and glow like a fluorescent lamp. By contrast, reflection nebulae, which appear bluer as opposed to reddish emission nebulae, glow softly simply by reflecting the tenuous light of bright stars that lie nearby.

As is the case with many reflection nebulae, NGC 7023 is fairly large and diffuse. Measuring 18' across and dimly lit by a 7th-magnitude star, NGC 7023 demands at least a 6-inch telescope for viewing even under dark skies. With a 10-inch or larger instrument, the nebulosity is easy to observe but appears completely featureless — a faint glow centered around the star that allows us to see it. A larger scope brings out more shape in the nebula but fails to reveal much more in the way of features.



NGC 7023 sketched by David J. Eicher using an 8-inch f/10 Celestron SCT at 50x.

David J. Eicher *is the editor of* Astronomy. *He has observed and sketched deep-sky objects for 36 years.*

New Products

See reports on 300+ products at www.Astronomy.com/equipment.

Attention manufacturers: To submit a product for this page, email **mbakich@astronomy.com**.

Digital SLR

Canon
Lake Success, New York

Canon designed its EOS 60Da DSLR camera for astroimaging. It contains an 18-megapixel CMOS sensor and a Hydrogen-alpha sensitivity three times higher than Canon's other cameras. It also boasts enhanced noise reduction and a 3.0-inch Clear View LCD screen.

Price: $1,499
[t] 800.652.2666
[w] www.usa.canon.com

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JMI Telescopes
Lakewood, Colorado

JMI's Heavy Duty Medium Size Universal Wheeley Bars can handle a maximum load of 300 pounds (136 kilograms). The unit adjusts to fit tripods with a tip-to-tip distance between 33 and 43 inches (84 and 109 centimeters). It raises the mount 3.5 inches (8.9cm) off the ground.

Price: $339
[t] 800.247.0304
[w] www.jmitelescopes.com

High-resolution cameras

Point Grey Research
Richmond, Canada

Point Grey's Flea3 FL3-GE-50S5 monochrome and color CCD firewire cameras incorporate 5-megapixel CCD chips, which can stream 2448x2048 images at eight frames per second. Each unit measures 1.14 by 1.14 by 1.18 inches (29 by 29 by 30 millimeters).

Price: $1,995
[t] 866.765.0827
[w] www.ptgrey.com

Wi-Fi telescope interface

Astro Devices
Sylvania, Australia

Astro Devices' Nexus is a Wi-Fi telescope interface that lets you connect your telescope to any of several planetarium software programs running on Wi-Fi compatible computing devices. Power comes from a 9-volt battery or external source between 9 and 25 volts DC.

Price: $269.95
[t] +61.402.158.680
[w] www.astrodevices.com

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Torrance, California

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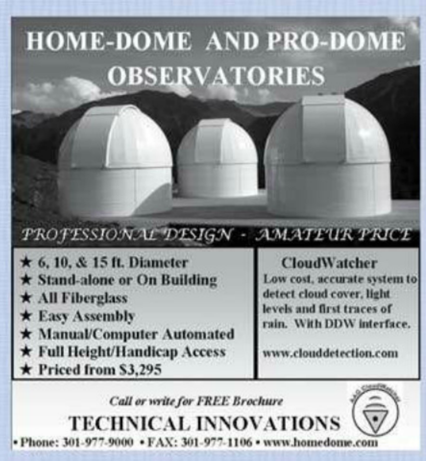
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Image Courtesy of Bob & Janice Fera (taken with the CDK17)

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3. Prizes and Odds of Winning. One drawing will be held on or around September 18, 2012 for the following awards: One (1) Grand Prize consisting of a SkyProdigy 6 (retail value $999.00). One (1) First Prize consisting of an AstroMaster LT 70AZ (retail value $129.95). One (1) Second Prize consisting of a SkyMaster 25x70 Binoculars (retail value $99.95). One (1) Third Prize consisting of a Celestron FirstScope w/accessory kit (retail value $59.95). Ten (10) Fourth Prizes consisting of a one-year subscription to *Astronomy* magazine (retail value $42.95 each).Cash equivalents of merchandise will not be awarded. Substituting prizes is not allowed. Any applicable federal, state, and/or local taxes are the responsibility of the winner. Odds of winning depend on the number of entries received. Total circulation for *Astronomy* magazine is 104,755. Sweepstakes void in Quebec and void where prohibited.

4. Validation and Acceptance. Winners in the *Astronomy* 2012 Summer Sweepstakes will be selected in a random drawing. Canadian prize awards subject to skill test requirement. By entering the sweepstakes, participants agree to be bound by these official rules and all decisions of Kalmbach Publishing Company. Sweepstakes entries void if not legible, not completed in full, not obtained legitimately, or if forged, photocopied, mechanically reproduced, late, or tampered with. The potential winners may have to sign and return an Affidavit of Eligibility, publicity release, and Release of Liability within fourteen (14) days of notification. In the event of non-compliance, alternate winners will be randomly drawn. No responsibility is assumed for lost, stolen, misdirected, or late entries or notifications. All sweepstakes entries become the property of Kalmbach Publishing Co. and will not be returned.

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COMING UP IN OUR NEXT ISSUE

Quest for the most distant objects

NASA/The Hubble Heritage Team (STScI/AURA)/C. Conselice (U. Wisconsin/STScI)

The search for the first structures in the universe has baffled astronomers for decades. But telescopes now on the horizon promise to shed new light.

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Queen's guitarist Brian May

A life in science and music

Astronomy: Roen Kelly

Black holes in our backyard

At least two dozen of these astounding objects lurk within the Milky Way

PLUS

- *Astronomy*'s third annual Star Products
- Wander the wonders in the King's constellation
- You should observe the Full Moon

Astronomy magazine

Star trails (Canon 40D DSLR, Canon EF-S 17–85mm f/4–5.6 Image Stabilized USM lens at f/4, ISO 3200, forty-four 80-second exposures, stacked) • Rogelio Bernal Andreo, Sunnyvale, California

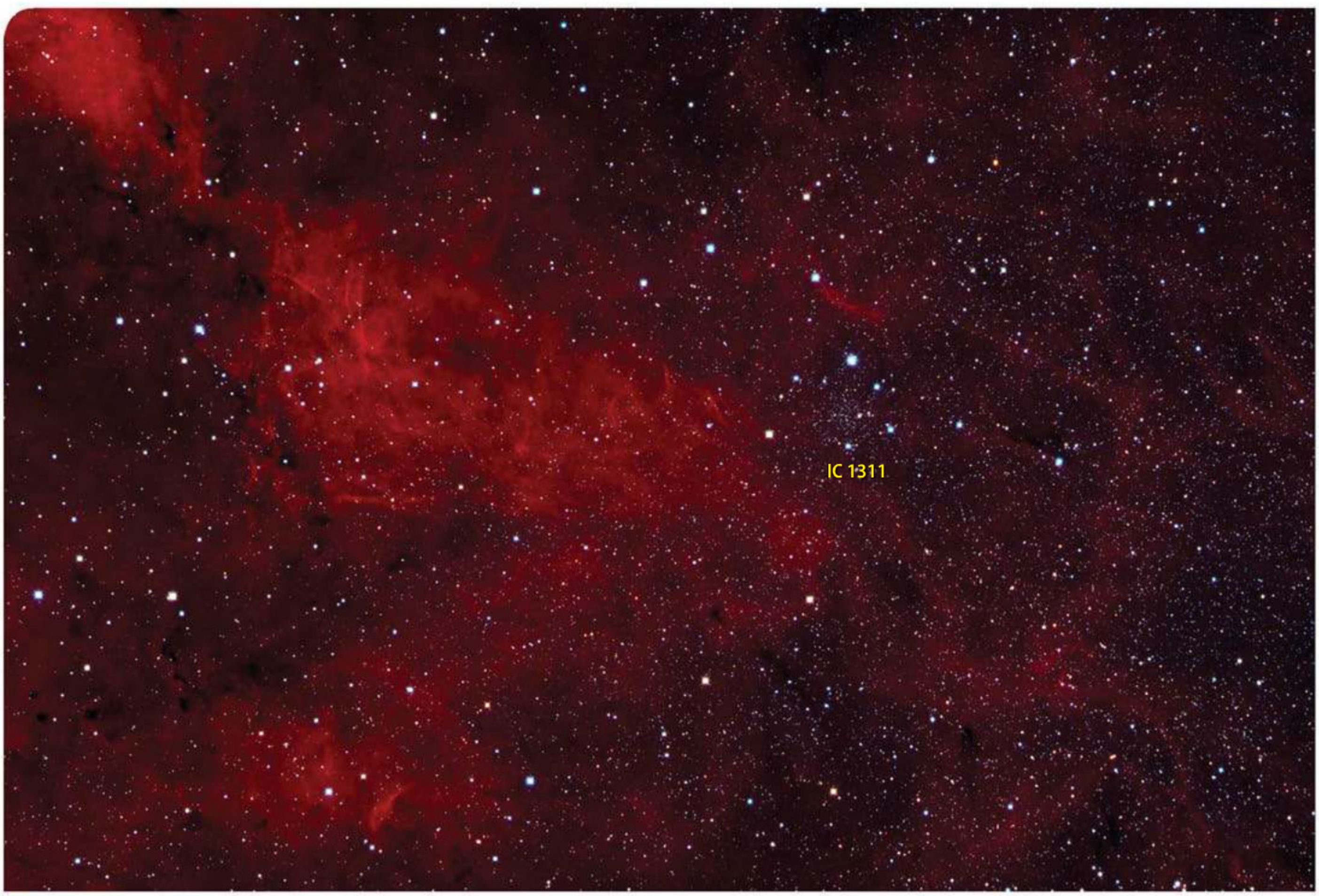
Imager's delight

While visiting his native Spain, Rogelio Bernal Andreo discovered his former dark-sky site was no longer accessible. So, using satellite imagery, he found a new site roughly an hour's drive from his childhood home. After 15 imaging sessions there, he confirmed his initial suspicions: The location is quite dark, it offers lots of space (behind an old ruined house), and it features an unobstructed horizon. On one of the nights, he took this series of exposures showing the stars' apparent motion over an hour. Mostly, however, he worked on a 54-frame macro-mosaic of Leo we'll feature in a future issue.

The Intergalactic Wanderer (NGC 2419) isn't famous for its brightness or beauty through a telescope, but rather because it's one of the Milky Way's most remote globular clusters. It lies some 300,000 light-years from our galaxy's core. (12-inch Newtonian reflector, SBIG ST-2000XM CCD camera, LRGB image with exposures of 6, 2, 2, and 2 hours, respectively) • Bernhard Hubl, Schlierbach, Austria

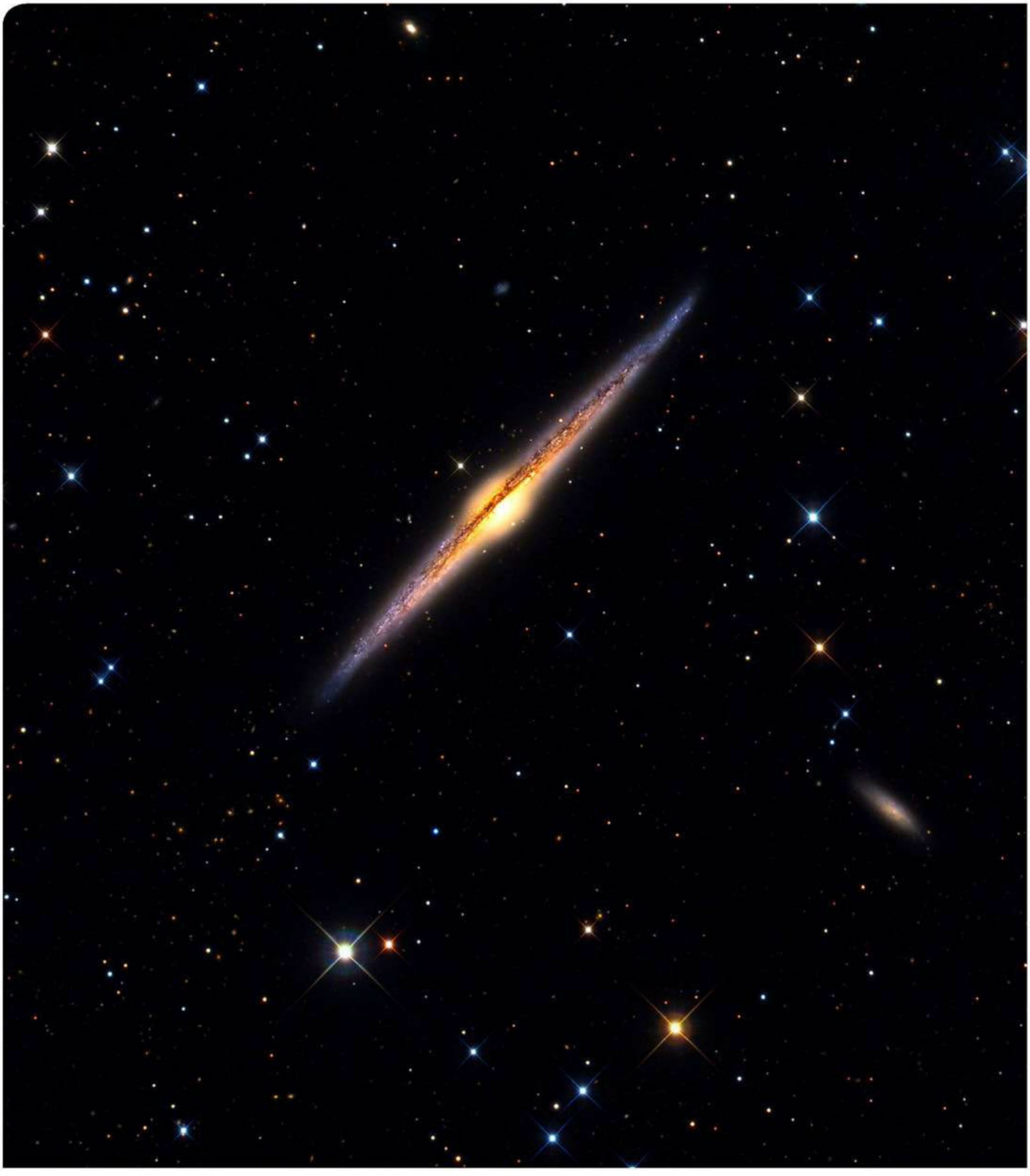
LBN 468 is a region of nebulosity in Cepheus that lies near the Iris Nebula (NGC 7023). At the upper left, you can see Gyulbudaghian's Nebula (arrow), a triangular patch surrounding the star PV Cephei. (10-inch Boren-Simon PowerNewt astrograph at f/2.8, SBIG ST-8300M CCD camera, LRGB image with exposures of 62, 5, 5, and 5 minutes, respectively) • Kfir Simon, Gan Yavne, Israel

Planetary nebula Abell 61 in Cygnus interacts with the interstellar medium, which explains the bright, distinct rim to the upper left compared to the fainter, disrupted rim to the lower right. (16-inch RC Optical Systems Ritchey-Chrétien reflector at f/8.9, Apogee U16M CCD camera, Hα/OIII/RGB image with exposures of 330, 210, 20, 20, and 20 minutes, respectively) • Don Goldman, Orangevale, California



IC 1311 (just to the right of center) is a magnitude 13.1 star cluster that lies in a region of sky filled with emission nebulosity. You'll find it 2.3° west-northwest of Sadr (Gamma [γ] Cygni [not shown]). (7.2-inch Takahashi E-180 hyperbolic astrograph, SBIG ST-10XME CCD camera, HαLRGB image with exposures of 120, 15, 15, 15, and 15 minutes, respectively) • Daniel B. Phillips, Oceanside, California

Send your images to: *Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures. Submit images by email to readergallery@astronomy.com.

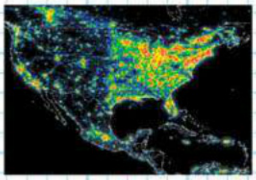


The Needle Galaxy (NGC 4565), an edge-on spiral in Coma Berenices, shines at magnitude 9.6. A dust lane runs the entire length of this object, masking much of the arms' brightness. If your telescope's aperture is 12 inches or more, try to view the magnitude 13.5 galaxy NGC 4562. From the Needle Galaxy, this faint spiral lies 13' southwest (lower right in this image). (14.5-inch RC Optical Systems Ritchey-Chrétien reflector at f/8, Apogee U16M CCD camera, RGB image with exposures of 220, 140, and 240 minutes, respectively) • Mark Hanson, Madison, Wisconsin

The Cosmic Grid

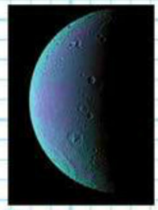
All things high, low, weird, and wonderful in astronomy and space science. **by Bill Andrews**

WEIRD



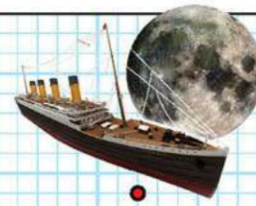
Political science

Arizona governor Jan Brewer vetoes a bill that would have destroyed the state's dark skies, thanks to awareness efforts by amateur astronomers. My faith in the system is restored!



Dione's freshness

NASA announces that its Cassini spacecraft "sniffed" the atmosphere of Saturn's moon Dione, finding a "Hint of Fresh Air," which must be nice after all those years in stuffy space.



Murderous Moon?

Texas State University-San Marcos asks, "Did the moon sink the Titanic?" Short answer: no. Long answer: nooooooooooooooooo.

The perfect name

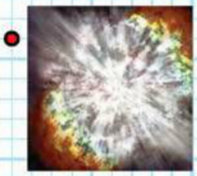
The 43rd Lunar and Planetary Science Conference features a presentation on Mars by French scientist John Carter. Man, studios are pulling out all the stops for their promotions!

Keepin' it cool

A *Slate* article asks, "Can *John Carter* make the red planet cool again?" Sounds like someone hasn't seen *Astronomy*'s August lineup!

1-click history

Amazon founder Jeff Bezos locates and plans to retrieve the main engines from the first stage rocket of Apollo 11, with NASA's blessing. No word yet on shipping costs.

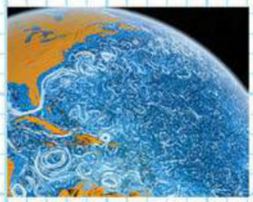


Supernovae studies

Astronomers studying exploding stars describe some as "showing such good table manners." Let that be a lesson to anyone struggling with gas during dinner.

André in the sky

Beatles tribute band Love & Mersey honors Dutch astronaut André Kuipers with the song "Back at the ISS (yeah)" — like it wasn't cool enough just being an astronaut.



Starry Ocean

NASA's Goddard Space Flight Center creates an animation showing off surface ocean currents — and Earth's post-impressionist phase.

Loony website

The website www.europaventuresllc.com shows off footage from a mission to Jupiter's moon Europa. Either it's promoting the movie *The Europa Report*, or NASA really got scooped.

HOT

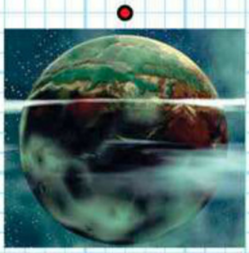
NOT

Totally awesome astronomy

The Royal Astronomical Society releases a story about comets and the Sun with the headline, "Supersonic snowballs in hell." Wow, I hope they put out an album sometime.

Enigmatic excitement

The U.S. Air Force indefinitely extends the mission of its X37-B — a secret, unmanned, experimental space plane called "game-changing" by the head of the Air Force Space Command. So, uh, yay?

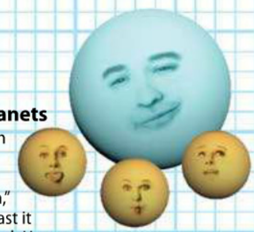


Science party!

This month's good news: Astronomers announce the possibility of billions of habitable planets in our galaxy, and a NASA official predicts the discovery of a "goldilocks planet" within the next two years.

Spinning *Spinoff*

NASA finds the perfect host for a public service announcement about everyday technologies the agency pioneered: equally derivative musician Will.i.am.

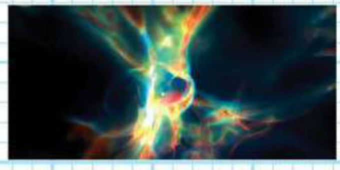


Personifying planets

NASA's Jet Propulsion Laboratory releases an article titled "The Many Moods of Titan," presumably to contrast it with that one-note jerk Uranus.

Ultra ultra screen

Stanford University animations promise to bring the universe "to the big screen." I knew movie screens were getting bigger, but I'm still impressed.



Anti-science party

A scientific study shows that conservatives' trust in science has fallen precipitously in the past 25 years. Evolutionists, climate scientists, and FDA scientists respond, "No kidding!"

Birds ... in ... space!

ISS astronaut Don Pettit helps demonstrate trajectories for the new game *Angry Birds Space*, developed with NASA's help. The ISS proves its usefulness once again.

PREDICTABLE

PHOTOGRAPHS: P. Cinzano/F. Falchi (Univ. of Padova)/C. D. Elvidge (NOAA NG Data Center) (Political science); Philip James (Univ. of Toledo)/Steven Lee (Univ. of Colorado)/NASA (Mars), Thinkstock/iStockphoto (sunglasses) (Keepin' it cool); NASA/GSFC Scientific Visualization Studio (*Starry Ocean*); NASA/ESA (André in the sky); NASA/JPL/SSI (Dione's freshness); NASA/JPL (Moon), Thinkstock/iStockphoto (Titanic) (Murderous Moon?); NASA/KSC (1-click history); NASA/CXC/M.Weiss (Supernovae studies); NASA/JPL/DLR (Loony website); U.S. Air Force (Enigmatic excitement); NASA/JPL (Planets), Thinkstock/iStockphoto (Faces) (Personifying planets); KIPAC (Ultra ultra screen); *Astronomy*: Alison Mackey (Anti-science party); NASA (Science party!); SOHO-EIT Consortium/ESA/NASA (Sun), Thinkstock/Brand X Pictures (guitarist) (Totally awesome astronomy); Angela George (Spinning *Spinoff*); NASA (Birds ... in ... space!)

JUST CALL IT
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THE **NEW** LX600™ WITH STARLOCK™

THE MOST RADICALLY ADVANCED FORK-MOUNTED TELESCOPE **EVER** PRODUCED

Meade®'s LX200® revolutionized 20th century amateur astronomy by making the sky accessible to all. Now Meade's remarkable LX600 with StarLock technology will irrevocably alter 21st century amateur astronomy by bringing stunning astroimages to your backyard.

The LX600 is a simple to operate, portable package that makes taking great astrophotos as easy as focusing your camera and opening the shutter. The collection of features and technology integrated into the LX600 is unavailable from any other manufacturer and cannot be duplicated by just attaching a set of add-ons to another scope.

▶ **StarLock** The LX600 integrates a unique star tracking and object finding system into the telescope mount. This integration allows the telescope to center your target perfectly in the field of view. Once centered, the star tracking system communicates directly with the motor drive system to automatically assure your scope stays locked onto its target with arcsecond precision. By locking onto actual stars, this automated optical tracking system delivers long-term guiding with pinpoint stars on astroimages despite misalignments, atmospheric refraction, periodic or other mechanical errors. This level of precision is unobtainable with systems using high precision encoders, software pointing models, large gears or PEC training — and all without the need of an external computer.

▶ **New f/8 Advanced Coma-Free™ Optical System** Meade has completely redesigned the OTAs with a new mirror mounting and focusing system to achieve true zero image-shift and includes a two-speed micro focuser. The scope features faster f/8 ACF™ optics giving you pinpoint stars all the way across the field of view. The optional custom-designed focal reducer makes your scope a full-frame, flat-field f/5 optical system at a fraction of the cost of an OTA only from other manufacturers.

▶ **All New X-Wedge™** Precision CNC-machined from ultra-ridged, aircraft-grade aluminum with smooth, accurate altitude and azimuth adjustments. Thirty percent more stable than competing equatorial wedges, the X-Wedge is the essential accessory for long exposure astroimaging.

▶ **Alt/Az Mode** In alt/az mode, the LX600 also makes for the best visual and short exposure experience possible. The LX600 performs Light Switch® fully-automated self alignment. StarLock will put every target dead center in the eyepiece and track with arcsecond accuracy so you can concentrate on the beautiful, wide fields of pinpoint stars created by the superb f/8 ACF optical system.

▶ **Portability** While you can achieve remarkable visual and imaging results from a suburban backyard, the ease of transporting an LX600 to a remote site will make you anxious to see what you can achieve under truly dark sky conditions.

For more information about the LX600 and Meade's complete line of products, visit meade.com or contact an authorized dealer.

LX600	**PRICE**	**WITH X-WEDGE**
10"	$4,499	$4,999
12"	$5,499	$5,999
14"	$7,999	$8,499
X-wedge separately		*$699*
f/5 field flattener/focal reducer		*$399*

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Mercury at its best

As October begins, three naked-eye planets grace the western evening sky. The brightest is **Mercury**, a normally inconspicuous object that puts on its finest show of the year this month. The innermost planet lies low in the twilight during early October, appearing 8° above the horizon 30 minutes after sunset. (Use binoculars if you can't spot it with naked eyes.) Mercury climbs higher and into a darker sky as it draws away from the Sun this month. When it reaches greatest eastern elongation October 26, it appears 17° high a half-hour after the Sun goes down and doesn't set for another 90 minutes.

The view of Mercury through a telescope changes quickly as October progresses. The planet spans 5" and shows a fat gibbous phase during the month's first two weeks. It grows to 7" and appears about 60 percent illuminated by greatest elongation. Its phase dwindles to half-lit by October's final evening.

Saturn accompanies Mercury in the twilight during October's first week. The two pass 3° from each other on the 6th. Mercury then shines at magnitude –0.3, a full magnitude brighter than Saturn. Unfortunately, the low altitude renders the ringed planet uninspiring when viewed through a telescope.

Mars resides much higher in the evening sky. Shortly after midmonth, the Red Planet passes just north of Antares, the 1st-magnitude red giant star that marks the Scorpion's heart. It's fascinating to see the two side by side. The star's name means "rival of Mars," and the objects' proximity gives you a good chance to compare their similar colors. A telescope reveals Mars' shimmering disk, which measures just 5" across and shows no detail.

Not long after Mars sets, you can find **Jupiter** rising in the northeast. The giant planet currently lies among the background stars of Taurus, between the Bull's horns. Jupiter's 45"-diameter disk shows lots of detail through a telescope, although its northerly declination means it doesn't climb higher than about 30°. For the best views, wait until it reaches its peak in the northern sky shortly before dawn.

Even a small scope reveals two dark belts that straddle the giant planet's equator. Under good conditions, observers typically see an alternating series of dark belts and bright zones. Also keep an eye out for the planet's four bright moons, which shift position from night to night.

Brilliant **Venus** hangs low in the east before dawn. It passes close to 1st-magnitude Regulus in Leo the Lion during October's first week. At magnitude –4.1, however, the planet shines more than 100 times brighter than the star. Although Venus lies 40° from the Sun early this month, it appears quite low in the sky because the ecliptic — the path of the Sun across the sky that the planets also follow closely — makes a shallow angle to the eastern horizon on spring mornings.

The best telescopic views of the planet this month come shortly after twilight begins. In early October, the planet spans 16" and appears about 70 percent illuminated. By month's end, Venus' disk measures only 13" across and shows an 80-percent-lit gibbous phase.

The Moon occults Jupiter on October 5/6 for residents in southern Australia and Tasmania. From Perth, the planet disappears behind the Moon's bright limb at 20h52m Universal Time (UT) October 5, which is 4:52 A.M. local time October 6. Jupiter reappears at 21h51m UT, almost precisely the time of sunrise.

The starry sky

In 1804, Karl Ludwig Harding (1765–1834) discovered the third asteroid, Juno, while working at Johann Schröter's observatory in Germany. To deep-sky observers, however, Harding's main claim to fame is the discovery of the Helix Nebula (NGC 7293). He found this object while compiling a catalog of some 120,000 stars.

The Helix lies in southern Aquarius, a dim region that climbs high in the northern sky on October evenings. You can find it about 10° northwest of 1st-magnitude Fomalhaut, the brightest star in Piscis Austrinus. As you close in on the area, look about 1° west of 5th-magnitude Upsilon (υ) Aquarii. The nebula lies one-quarter of the way from Upsilon to the similarly bright star 41 Aqr.

The Helix belongs to a class of objects known as planetary nebulae. These objects form near the end of a Sun-like star's life. As the star starts to run out of nuclear fuel, it swells into a red giant. The bloated object has at best a tenuous hold on its outer layers, and pulsations can drive off this gaseous material. The star's core remains as a white dwarf — a hot remnant that radiates lots of ultraviolet light. This radiation excites the atoms in the gaseous envelope and causes them to glow.

Although the Helix has an impressive total magnitude of about 7, it is difficult to spot because its light spreads out over such a large area. The nebula spans 15' by 12', which makes it nearly half the diameter of a Full Moon.

Under a dark sky, the Helix shows up through 7x50 binoculars. Still, the nebula is far more impressive through a telescope. Just make sure to use low power so you have a fairly wide field of view. The first time I viewed the Helix, I was taken aback to realize that it filled much of the telescope's field.

If you'd like a challenge, see if you can spot the nebula's central white dwarf star. Glowing dimly at magnitude 13.4, it's beyond the range of the smallest telescopes, but 20-centimeter or larger instruments show it under good conditions.

StarDome

The all-sky map shows how the sky looks at:
10 P.M. October 1
9 P.M. October 15
8 P.M. October 31

Planets are shown at midmonth

How to use t
latitude. Loca
east, ar
sc

Magnitudes
- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

his map: This map portrays the sky as seen near 30° south
ted inside the border are the four directions: north, south,
nd west. To find stars, hold the map overhead and orient it
o a direction label matches the direction you're facing. The
stars above the map's horizon now
match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly

October 2012

Calendar of events

1 Mercury passes 1.8° north of Spica, 2h UT

3 Venus passes 0.1° south of Regulus, 8h UT

4 Jupiter is stationary, 14h UT

5 The Moon is at apogee (405,160 kilometers from Earth), 0h43m UT

The Moon passes 0.9° south of Jupiter, 21h UT

6 Mercury passes 3° south of Saturn, 7h UT

7 The Moon passes 0.9° south of asteroid Ceres, 5h UT

8 Last Quarter Moon occurs at 7h33m UT

12 The Moon passes 6° south of Venus, 19h UT

15 New Moon occurs at 12h03m UT

17 The Moon is at perigee (360,672 kilometers from Earth), 1h00m UT

The Moon passes 1.3° north of Mercury, 2h UT

18 The Moon passes 2° north of Mars, 13h UT

20 Mars passes 4° north of Antares, 6h UT

The Moon passes 0.08° south of Pluto, 14h UT

21 Orionid meteor shower peaks

Asteroid Vesta is stationary, 7h UT

22 First Quarter Moon occurs at 3h32m UT

24 The Moon passes 6° north of Neptune, 16h UT

25 Saturn is in conjunction with the Sun, 9h UT

26 Mercury is at greatest eastern elongation (24°), 22h UT

27 The Moon passes 5° north of Uranus, 10h UT

29 Full Moon occurs at 19h49m UT

31 Asteroid Ceres is stationary, 21h UT

For definitions of terms, log onto www.Astronomy.com/glossary.